SCF II Project

Procedures for the certification of performance of large custom-made solar thermal systems, with particular emphasis on the modelling tools (SK-LCMSTS)

Deliverable: D4

"Example certification" of performance of large custom-made solar thermal systems

S. Babalis, J.E. Nielsen

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1. Introduction

Scope of this report is to constitute an example of the document required by the manufacturer in order to apply to the Certification Body and obtain the Solar Keymark certification for a specific custom-built solar thermal installation.

In order to develop the contents of this report the provisions of the EN 12977-1 and EN12977-2 Standards along with those given in the En12975 and EN12976 Standards have been considered.

With reference to the table of contents, the solar collector panel field is described in *Chapter 3* while the solar collector data along with the test performance and Solar Keymark details can be found in *Appendix A*.

Information about the hot water storage tank can be found in *Chapter 4* whereas details on the water circuit and flow control components can be found in *Chapter 5.* The hydraulic and thermal components of the installation are described in *Chapter 6*. In *Appendix B* the hydraulic connection diagrams and the technical specifications of the solar field, are reported.

Specifications of the measuring sensors used in the installation are described in *Chapter 7* while the electrical and control system is described in *Chapter 8*. In *Appendix C* the electrical system diagrams are reported.

Commissioning and start up procedures of the installation are reported in *Chapter 9* whereas operation and maintenance provisions are reported in *Chapter 10* and *Appendix D*.

Finally the predicted performance of the designed solar thermal system along with the evaluation of the facility as installed, is reported in *Chapter 11* using the reference meteorological data reported in *Appendix E*.

2. Description and Classification of the system

This custom-built solar thermal system has been installed in order to cover the hot water demands of the facilities of the Solar & Energy Systems Laboratory of NCSR "Demokritos" and used also for experimental purposes.

After a series of preliminary calculations it was obtained that in order to efficiently provide the requested hot water volume a 5000 l hot water storage tank coupled with a solar field of approximately 66 m^2 of selective type solar collectors was the most appropriate solution. A solar field consisted of 40 collectors with an aperture area of 1,78 m^2 each (aperture area of the solar collector used) was finally selected and adopted.

Considering all the possible alternatives the most suitable and convenient place for the installation of the solar panel field was the one of the two identical moving roofs of the building used for offices situated in the premises of the Solar & Energy Systems Laboratory of the NCSR "DEMOKRITOS". This building was from the beginning provided with a system of two identical and independently moving roofing parts, actually used for space conditioning purposes (summer ventilation and cooling and winter space heating with the sun) .

All the other equipment including, hot water tank, pumps and the relative piping and valves have been installed on a concrete rack, made for this purpose, in a place beside the roof at 1 m level from the ground.

The solar thermal plant is divided into two parts that in general correspond in the two main branches of the installation. The complete hydraulic diagrams of the water-glycol as well as of the water side as in situ realized are reported in *Appendix B*.

The first branch, using water-glycol as working fluid, passes through the hot side of the plate heat exchanger by means of a pump, receiving the heat collected from the solar collector field.

The other branch, using water as working fluid, passes through the cold side of the plate heat exchanger by means of a pump, accumulating the heat produced by the solar field into the storage tank.

The hot water storage is consisted of a 5000 m^3 capacity tank. The water circuit is integrated with the necessary flow control and monitoring components consisted of command valves, temperature and pressure sensors, accumulators, drain and reducing valves in order to ensure the correct, safe and efficient operation as well as the control of the thermal installation.

In the next chapters the specifications of all the component used to the installation with the relative drawings and layouts when necessary, are reported. The manufacturer and the type of the solar collectors as well as of the storage tank was intentionally not specified in order to avoid preferential treatment of specific manufacturers nevertheless all the technical specifications and data reported are the real ones.

According to the EN 12977-1 this solar thermal system can be classified as **Class A**, because uniquely designed by combining various components for the specific situation which could be used for hot water preparation. As required by the

Standard the collector area is greater than 30 m^2 and the store volume is greater than 3 m^3. Furthermore the store and the collector array are located in one building for which the heat/cool is provided. No seasonal store and no heat distribution network outside the building are included. Therefore the requirements, as stated in the EN 12977-1 Standard, refer to the EN 12977-2 and EN 12977-4 Standards

3. The Solar collector panel field.

3.1 Characteristics of the solar collectors.

After a thorough evaluation of economic and efficiency parameters of different flat-plate solar collectors the type AAA manufactured by COMPANY A was selected for the construction of the solar field. The solar panel field consists of 40 flat-plate Solar Keymarked solar collectors of the COMPANY A, type AAA divided in two groups of panels. After a thorough examination of the possibilities offered by this project it has been decided to install the hydraulic system following the connection reported in the hydraulic scheme in *Figures 20, 21* and *22*.

This type of solar collector is made using a commercial type aluminum profile as a structural element to form a rectangular frame with a gross area of 1.93 m^2 and an aperture area of 1.78 m^2.

The collector's absorber has a total area of 1.73 m^2 and is realized by welding nine finned ∅ 7 mm copper pipes on the two ∅ 20 mm copper headers pipes forming an equidistant grid with a distance of 6 cm between each riser.

The grid of selective coated fins, having a thickness of 0.02 mm, realizes a «black» solar energy-absorbing surface of the selective type.

A single envelope of low iron tempered glass is placed in a distance of 25 mm over the solar absorber surface while the backside is insulated using rock wool and polyurethane foam panels of appropriate dimensions.

In order to establish the performance of the solar collector used in the installation a testing task have been carried out and the relative test results with the technical specifications and the test performance are attached in the *Appendix A*. In the same appendix a Solar Keymark data sheet is also reported.

Panoramic view and partial views of the solar collector field are reported in *Figures 1, 2* and *3*.

3.2. Set up and installation of the solar collector field

A metallic base-frame infrastructure, suitable for the installation of the solar panel field mounting rests, has been designed on purpose and installed on the movable roof of the office building of the Solar & Energy Systems Laboratory of the NCSR "DEMOKRITOS". This metallic infrastructure was considered necessary in order to consist a permanent base-frame for future experiments and avoid the damage of the roof made of concrete.

All parts of the metallic base-frame infrastructure are made of Fe 360 beams, appropriately dimensioned from a previous structural analysis.

The solar collectors of the field have been arranged in two identical groups of 20 collectors, each one consisted of four sets of five collectors.

Each one of the two collector sets was placed on their own metallic supporting rests. These supporting rests are firmly bolted on four groups of UPN 60×30 parallel beams placed in a distance of 1.71 m between them. This was the distance between the front and the rear base mountings of the rests.

The UPN 60×30 beams was firmly bolted on the traversing L60×6 beams by means of 70 mm pieces made of L30×3 square welded on the body of the UPN beams. These bolting pieces are welded in equal distances of 2 m achieving the stability and the strengthens of each collector rest. The connection is achieved by M10×30 bolts ensuring this way the capability of placing other type of solar collectors in future by changing the relative mounting rest distances (exchangeability).

After the roof frame is locally cleaned of the concrete floor, metallic mountings (made of 190 mm length L60×6 squares) are placed vertically and welded firmly on the frame nodes of the roof. The parallel L60×6 squares are traversing the roofing in the North-South direction and in distances of 2 m between them. The traverses are firmly welded on the metallic mountings in a distance of 100 mm from the roof concrete surface. The vertically placed 190 mm mountings are welded in any node of the existing moving roof frame forming a 2×2m mesh.

The local small damages procured on the concrete floor of the moving roof are repaired using an appropriate concrete base material and successively covered with waterproofing synthetic coating.

All the metallic parts of the base-frame are sandblasted and covered with one layer of primer and one layer of final coating

A partial view of the base frame of the solar field can be seen in *Figure 3*.

Figure 1: *Panoramic view of the solar collector field as installed on the building roof*

Figure 2: *View of the front side of the solar collector field*

Figure 3: *View of the rear side of the solar collector field*

4. Water tank.

4.1 Description of the water tanks.

After a careful evaluation of economic and efficiency parameters of different hot water tanks either in Greece as well as abroad the boiler type BBB of the COMPANY B has been selected for installation in combination with the solar field.

1 Heat exchanger outlet
2 Heat exchanger inlet
3 Heat exchanger venting valve
4 Mg Anode
5 Thermometer well tap
6 Relief valve
7 Water outlet
8 Connection to the electric supply
9 Recirculation
10 Water inlet
11 Drain
12 Auxiliary water outlet
13 Auxiliary water inlet
14 Data plate

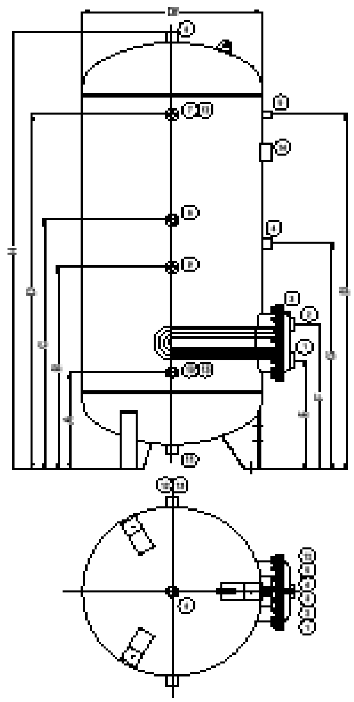


Figure 4: *Schematic of the water storage tank*

The dimensions of the hot water tank selected for the application, in relation to the schematic diagram reported above in *Figure 4*, are as follows:

Nominal Capacity	Df	H	A	B	C	D	E	F	G
[lt]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
5000	1600	3040	648	1428	1668	2448	748	948	1648

Construction

This type BBB of COMPANY B boiler is made of 20mm welded carbon steel plate and for anticorrosive protection reasons is internally enamelled and externally coated with special protection paint. The storage tank is equipped with a gasketed window suitable to receive a tube heat exchanger if requested (in our case the heat exchanger is not installed) and fabricated in vertical configuration for space-saving reasons. The tank is suitable for home and industrial applications used for production and storage of hot water as well as for sanitary purposes.

The selected tank was fabricated with a capacity to withstand at 6 bar working pressure in the temperature range from 5 ^{o}C to 99^{o}C. Was also provided with an Mg anode, which is the most diffused and cost-efficient system suitable to ensure the galvanic protection of the internal part of the hot water circuit. As already known the Magnesium, because of its low electrochemical potential, is literally disintegrated when corrosive processes are present, giving in this way protection of the other metallic parts of the tank working as a cathode. The Mg anode should be periodically inspected for his effectiveness in order to prevent the complete consumption of the material and therefore the incapacity to protect the installation. The consumption of the anode depends on different parameters namely the surface/volume ratio of the boiler, the anode dimensions, the chemico-physical properties of water in use, the working temperature.

Thermal insulation

The thermal insulation of the storage tank is currying out the most important part in the containment of heat losses having a direct influence in the thermal efficiency of the whole plant. The tank type BBB of the COMPANY B is completely insulated with a 100 mm of soft polyurethane foam externally jacketed in sky (a leather-like finishing material).

4.2 Installation of the hot water circuit.

The installation of the storage tank was executed by following the specifications of the manufacturer providing all the proposed appropriate thermal protection components, i.e. automatic venting and relief valves, temperature sensors and consumable anodes etc.

All the inlet and outlet pipes of the tanks are equipped with ball valves for maintenance and replacing reasons.

In *Figure 5* below a schematic diagram of the piping connections, as proposed by the manufacturer and followed for this application, is reported.

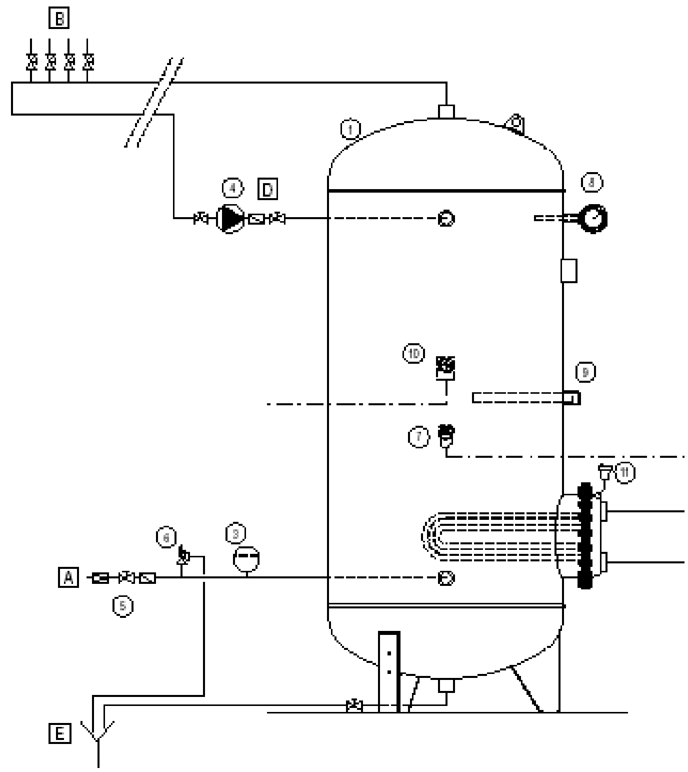


Figure 5: *Schematic of the hot water tank connection*

A	Hot water inlet	**1**	Boiller
B	Aux hot water inlet	**3**	Expansion tank
D	Recirculation	**6**	Relief valve
E	Drain	**8**	Thermometer well
9	Mg anode		
4	Water pumping system (pump, shutoff valve, check valve)		
5	Water filling system (reduction valve, shutoff valve, check valve)		

4.3 Set up and installation of the water tank.

The water tank was placed, in the working position, on a metallic pedestal made of Fe 360 beams of the HEA 200 type. The metallic beams are welded together forming a grid in order to ensure the structural stiffness and load capacity.

The supporting capacity of this metallic pedestal is, for security reasons, beyond the necessary to support the weight of the tank full of water. The tank was provided with three mounts firmly bolted in their positions on the metallic pedestal.

A view of the base frame and the 5000 l hot water storage tank can be seen in the *Figure 6* below.

Figure 6: *Lateral view of the solar collector field with the storage tank and the electrical and control panel boards*

5. Water circuit outfits and flow control components.

5.1 Piping.

The complete water pipe circuit was made of phosphor-deoxidised brass having clean and smooth internal and external surface without any visual faults. For this type of pipes the DIN-1786/1969 (to the nominal diameter of Ø54mm) and the DIN-1754/1969 (for higher diameters) are followed, which corresponds to the light medium hardness category pipes. They are fabricated according the solid drawing process and should not be redrawn in any case (this condition is satisfied for the normal commercial brass pipes).

They are supplied as fabricated in 3m straight pieces with clean and right cut ends. The thickness shall not be different of more than ±10% from those proposed by the mentioned regulations (this condition is satisfied for the normal commercial brass pipes). The thicknesses of the pipes according to the nominal diameter (light medium hardness category) are the following:

Nominal pipe Diameter (mm)	**Minimum pipe thickness** (mm)
15 - 20	1,0
28 - 42	1,5
54 - 88,9	2,0

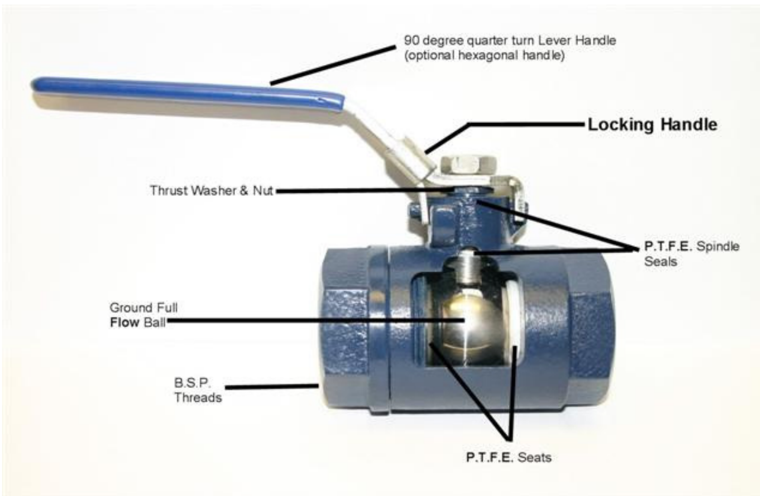
All connections have been made using capillary soldering according to the DIN regulations.

5.2 Valves.

All the interruption elements, i.e. shut off, regulation and check valves, are suitable to withstand the maximum pressure and temperature of the relative circuits. According to the DIN-2401 regulations, they are made using phosphor brass with class ND-10 thread, until the nominal diameter of Ø2”.

Shut-off valves (*ball valves*)

The shut-off or ball valves are mainly used for fast interruption of the water flow from and to a specific component. The ball valves are quarter–turn type in which a drilled ball rotates between resilient seats, allowing straight-through flow in the open position and shutting off flow when the ball is rotated 90 deg and block the flow passage (see the picture below).



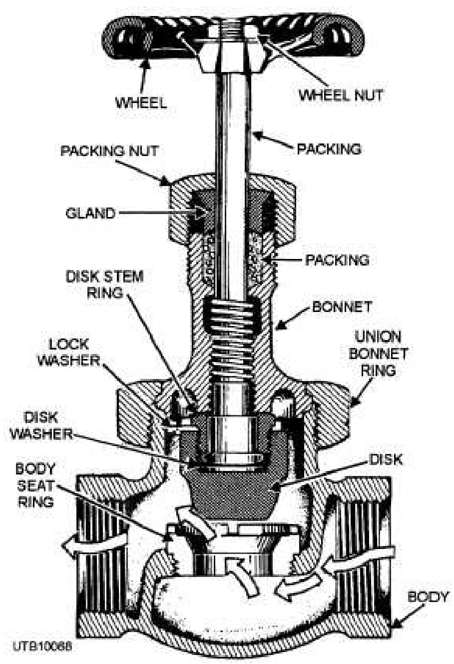
All the shut-of valves used are made of phosphor brass and suitable for a quarter-turn operation.

The valves are connected by means of their threaded ends to the relative piping using special adaptors suitable to withstand a nominal working pressure of 10 bars and water temperature of 120°C.

Regulation valves (*globe valves*).

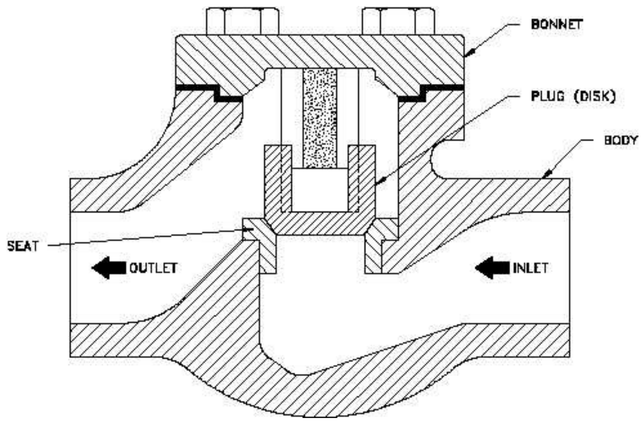
The regulation valves are of the globe type used for regulating (throttling) the water flow rate. The globe valve is of multiturn type in which closure is achieved by means of a disk or plug that seals or stops the fluid on a seat generally parallel to the line flow. The globe valves are placed before each set of five solar collectors (connected in serial or parallel mode) in order to regulate the flow rate.

The valves are connected by means of their threaded ends to the relative piping using special adaptors suitable to withstand a nominal working pressure of 10 bars and water temperature of 120°C.



Check valves (*non-return valves*)

The check valve is designed to check the reversal of flow. In the desired direction fluid flow opens the valve and the reversal of flow closes it. The check valves are positioned in those places the reverse flow is undesired i.e. between the tanks, before the automatic control valves etc.



The check valves used are of the lift type which is similar in design to a globe type valve except that the disk is lifted by the forward line flow pressure and closed by a spring and the backflow.

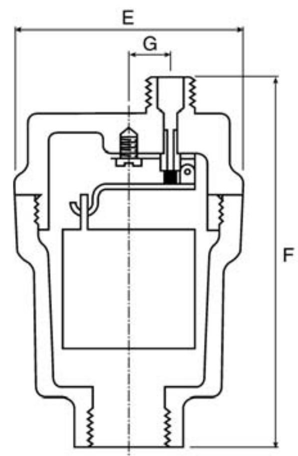
The valves are connected by means of their threaded ends to the relative piping using special adaptors suitable to withstand a nominal working pressure of 10 bars and water temperature of 120ºC

Automatic venting valves

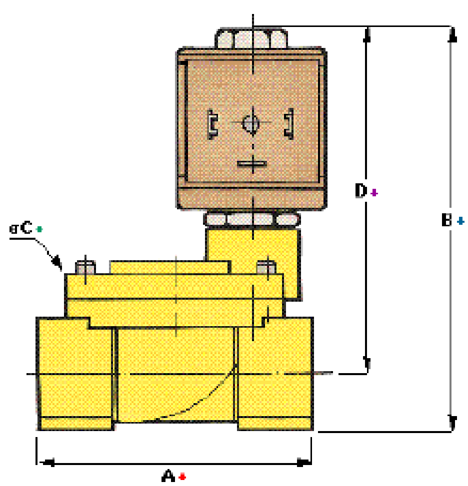
The automatic venting valves are designed and used to automatically vent the amount of air trapped into the water circuit (see the picture in side).

They are equipped with a floating element that seals the opening (vent) in absence of gas and they are incorporating a check valve in order to seal the circuit if the valve is removed.

The nominal diameter of the automatic vent valves are ∅3/8" and they are suitable for a working pressure of 8 bars.



Automatic on/off valves



The electric on/of valves are 2/2 way, normally closed valves suitable for continuous duty. They are directly controlled by a solenoid supplied with a voltage of 24 V.

The valve body is made of brass and the magnetic parts in contact with the fluid of stainless steel. The seals are made of EPDM plastic.

The valves are capable to withstand a working pressure of 15 bar and a maximum temperature of 130 ºC.

A schematic layout of the solenoid on/off valve is reported in side.

5.3 Balancing valves.

Correct balancing of circuits ensures optimum efficiency of the system and can therefore help reduce energy consumption. For this reason the TACONOVA type AV23 balancing valves have been adopted to facilitate fast and accurate adjustment of flow rates through solar collectors water-glycol circuits. The particular valves are provided with visual flow indication for direct reading and balancing. The required flow rate can be set without the need to consult curves, conversion charts or invest in expensive electronic commissioning equipment.

The valve may be installed in vertical, horizontal or inclined position. Care has been taken in order to ensure that the arrow is pointing in the direction of the flow.

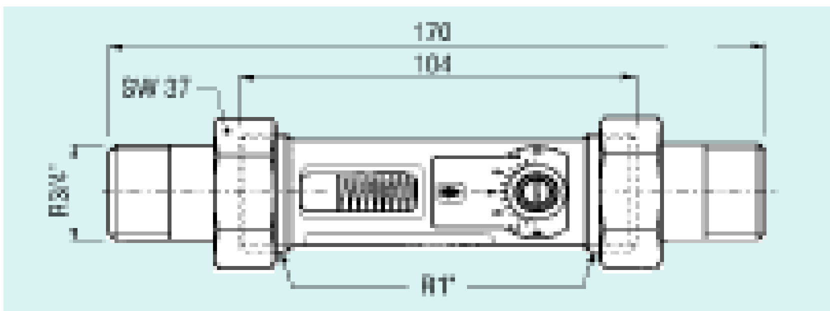


Figure 6: *Schematic of an AV 23 balancing balve*

The advantages offered by the application of the balancing valves are the following:

- Precise and quick balancing without diagrams, tables or measuring devices.
- Flow rate displayed directly in l /min.
- Regulating valve with adjustment scale.
- Regulating valve with isolating facility (rest leakage possible).
- Can be installed in any position.
- Connection range fitting to the system.

Specifications

The nominal regulation flow rate of the 1” nominal diameter AV23 valves is in the range of 4-15 lt/min. The max. operating temperature is of 100 °C and the max. operating pressure of 10 bar. The valve housing is made of standard brass Ms 58, the sight glass of high-grade plastic and the seals are made of EPDM rubber. The measuring accuracy is of ±10% in the highest nominal flow which is satisfactory for balancing purposes.

Operation

Measurement of the flow rate through the valve can be set by turning the adjustment screw until the required flow rate is read on the back edge of the float, which is situated within the measuring cylinder.

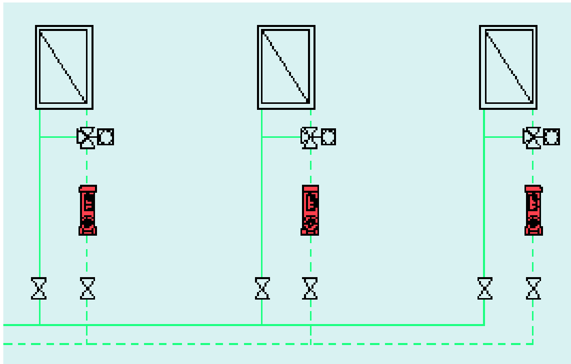


Figure 7: *Schematic connection diagram of the AV 23 balancing valve*

5.4 Flow indicators (variable area flow meters).

The variable area flow meters are used as flow indicators in the water-glycol circuit of the solar collectors field. The flow meters are installed in a vertical pipe run with flow from bottom to top just after the pumps pressing the “working fluid” to the solar collector field.

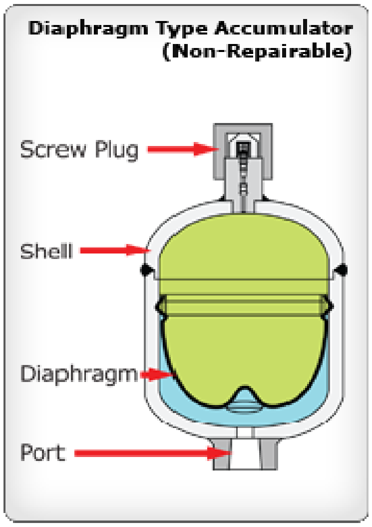
The glass tube allows direct reading of the flow.

The variable area flow meters are for liquids and gases and feature a tapered glass tube operating on the float measuring principle. They have a common basic design and standard connections.

Measuring ranges (100 % values, Water 20 °C): 0.16 to 10 000 l/h
Turn-down ratio 10 : 1
Accuracy class (to VDI / VDE Code 3513, Sh. 2): 1.0
Glass measuring cone length: 300 mm (11.8”)

The measuring cones are made of high temperature-resistant stress free borosilicate glass. Cones and floats are individually replaceable (accuracy class 1.6).

5.5 Accumulators.



The heat storage tank is served by a system of two accumulator units for prompt response reasons. The first one is of 300 lt capacity and the other, of lower capacity, 100 lt both capable to withstand at a 6 bars pressure.

They are of the membrane type according the DIN-4751/2 Standard. They are consisted of a spherical or cylindrical tank of proper capacity full of nitrogen gas pressurized at a pressure relative to the geodetic pressure of the installation and suitable of a maximum working pressure of 6 bars.

The selection of the accumulators has been done taking into account the working fluid volume and the final working pressure of any separate circuit.

Each one of the accumulators is accompanied with the relative relief valves and the necessary fluid supply system complete with pressure reducing device

The water-glycol solar collector circuit, was equipped with a normal 50 lt accumulator capable to withstand at a pressure of 6 bars.

5.6 Pipe insulation.

In hydraulic installation with a solar collector field of those proportions and large storage tanks the thermal insulation of all parts should be considered as imperative.

The insulation specification of the storage tank has been mentioned in the relative paragraph. All the other piping and fitting elements as well as the valves and the thermal components (heat exchanger) are completely insulated in order to minimize the thermal losses.

The material used for the insulation is the ARMAFLEX which is a black polyethylene foam with predefined dimensions. For pipes until the nominal size of ∅2” a jacketed sleeve with 13 mm thickness is used. The larger dimensions components are insulated with a 13 mm thickness ARMAFLEX insulating plane sheet.

All the pieces of insulation are coated with a three layer insulating varnish in order to protect the insulation from the environmental conditions.

6. Hydraulic and thermal components.

6.1 Water pumps.

All the pumps used are of the centrifugal type, positioned horizontally and suitable for water temperature up to 120 ^oC.

The pump used for the circulation of the water – glycol "working fluid" inside the circuit of the solar collectors is a WILO MHI 406 M of 2 kW power and a nominal capacity of 6 m^3/h at a pressure drop of 40 mWG.

The water from the plate heat exchanger to the 5000 m^3 storage tank is circulating by means of a WILO MHI 803 M pump with 1,6 kW power and a nominal capacity of 8 m^3/h at a pressure drop of 20 mWG.

6.2. Heat exchanger.

The heat exchanger is consisted of a number of corrugated plates clamped together in a frame and sealed at the edges by means of gaskets. The plate pack is assembled between a frame plate and a pressure plate and compressed by tightening bolts.

The frame consists of a fixed frame plate, a moveable pressure plate, an upper carrying bar, a lower guiding bar, a support column and tightening bolts with nuts and washers. The plates are fitted with a gasket, which seals the channel and directs the fluids into alternate channels. The number of plates is determined by the flow rate, physical properties of the fluids, pressure drop and temperature program.

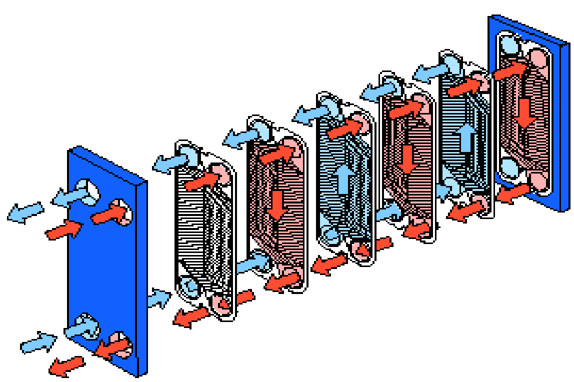


Figure 8: *Schematic layout of the plate heat exchanger flow pattern*

Specifications

The plate heat exchanger used for this application is a 32 plates GEA Ecoflex VT04 PHK/CD-16 with a heat capacity of 86000 Btu/h.

The flow rate in the hot side (water-glycol 15%) is of 6 m^3/h and in the cold side (water) of 8 m^3/h.

Working principle

The plates and the pressure plate are suspended from an upper carrying bar and located by a lower guiding bar, both of which are fixed to support columns. Channels are formed between the plates and corner ports are arranged so that the two media flow through alternate channels. The heat is transferred through the thin plate between the channels, and complete counter current flow is created for highest possible efficiency. The plates have ports at the corners and the gaskets are so arranged that the two media flow through alternate passages between the plates. The two media are separated by the plates and cannot be mixed. Heat is transferred through the plates, from the hot medium to the cold.

The corrugation of the plates provides a passage between the plates, supports each plate against the adjacent one and enhances the turbulence, resulting in efficient heat transfer. A unique distribution area provides an even flow over the plate surface. The plates are reversible and have parallel flow, which means only one type of plate is needed. The plates are supplied with glue-free Clip-On gaskets, which are easy to replace.

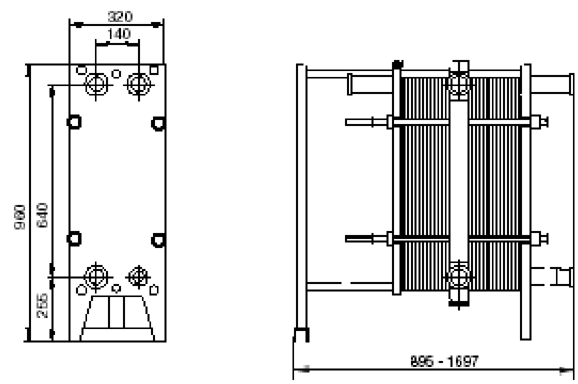


Figure 9: *Dimensional layout of the plate heat exchanger*

7. Sensing elements

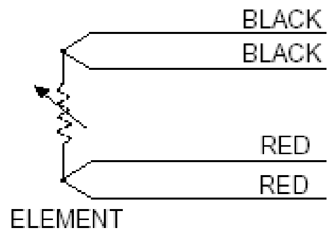
7.1 Pt100 temperature sensors

For the temperature measurement, in points that affect system control, the DIN 1/10 class Pt100 type sensors having a sensing element made with a 100 ohm platinum (a = 0.00385), have been adopted. This type of sensor offers low response time and high accuracy in combination with reliability of probe's construction. They are used to detect the temperature value in the outlet of each part of the solar collector field as well as the temperature inside the water tanks.

The probes used in this application are assemblies composed of a sensing element (the Pt100 sensor), a sheath, a lead wire, and a termination or connection. Probes are terminated in a connector head, for quick disconnect and inspect the wiring.

The sheath is a closed end tube that immobilizes the element, protecting it against moisture and the environment to be measured. The sheath also provides protection and stability to the transition lead wires from the fragile element wires.

The Pt100 resistance temperature sensor operates on the principle of the change of the electrical resistance in a wire as a function of temperature. The Pt100 sensors are connected according the 4-wire configuration. This configuration, denoted in the figure nearby, provides two connectors to each end of the sensor. This construction is used for measurements of the highest precision.



7.2 Thermocouple temperature sensors

The measurement of the temperature at the rest of the water circuit (i.e. water inlet and outlet of all thermal components) have been carried out using thermocouple sensors of the K type.

The K type thermocouple sensors are made of Cromega – Alumega alloys and recommended for a wide temperature range (-200°C to 1200°C). They present an accuracy of ±0.7°C and they are teflon insulated.

They are all fabricated from the same wire reel, cut to the exact wire length for the application, by using a special Mercury welding voltaic arc technique.

Figure 10: *Detailed view of the collector inlet flow pipe showing the regulation valve, the balancing valve and the thermocouple temperature sensor assembly.*

Figure 11: *Detailed view of the collector outlet flow pipe showing the automatic venting valve, the thermocouple temperature sensor and the shut-off valve assembly.*

7.3 Flow rate sensors

The flow meters used in the installation are the RT-025AK016P type made by the HONSBERG & CO with a nominal metering range from 1.6 to 16 m^3/h having a max flow rate of 19 m^3/h and a tolerance of ±1% of full scale from <10 to 100% of metering range (inclusive linearity and repeatability).


RT-020AK004P

The sensors are fabricated for max media temperature of 100°C, tolerating particles 0.5mm having an average pressure loss 0.3bar at Qmax.

This HONSBERG type RT flow rate sensor, with 1" nominal diameter, was preferred because consists in a full stainless steel enclosure and a stainless steel turbine arranged in sapphire cups. This type of flow sensor provides flow-proportional revolutions, which are detected by a pre-triggered Hall sensor having high accuracy, no magnetic bearings in the wetted chamber and high-pressure duty.

The sensors are coupled with the EFI converter with a 4 – 20 mA output. The transducer EFI provides the 24 VDC regulated power supply of the sensor and therefore no separate wiring is necessary for the sensor supply. The EFI transducer transforms frequency signal to a 4(0) - 20 mA signal.

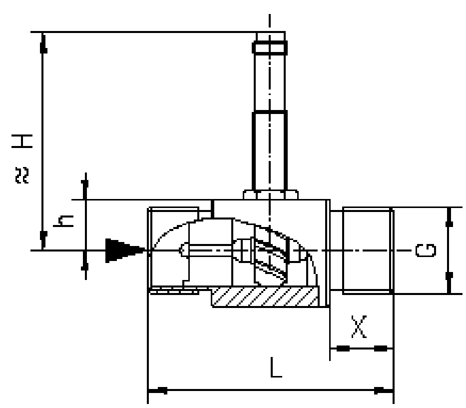


Figure 12: *Schematic diagram of the HONSBERG type RT flow rate sensor*

7.4 Meteorological data measurement system.

The monitoring system was also equipped with a complete meteo station providing all the necessary data information of the environment.

The system is consisted of a temperature sensor and a relative humidity sensor protected into an appropriate protecting cover. Wind speed and wind direction detection as well as pyranometers for the horizontal inclined and diffuse solar irradiation evaluation at each measuring time, are also provided.

The system is placed on a 3 m must and has the capability to take measurements of the parameters continuously and storage them in a backup system for download.

Figure 13: *View of the meteorological station*

8. Electrical installation & control system

8.1 Electrical system

The complete wiring diagrams for the power and automation systems of the electrical installation are reported in *Appendix C*. The electrical coponents are equipped with the relative swiches and the appropriate protection devices according to the loacal regulations.

The control of the pumps and the automatic on/off valves was realized by means of relay switches activated by low voltage (24 V) control systems of the appropriate size and type.

Figure 14: *View of the main control panel*

8.2 Solar field control panel.

This panel is made appropriatelly for the installation of the controlling board of the water-glycol circuit pumps. The controller is based on the microcontoller PIC16F87X of the MICROCHIP TECHNOLOGY INC. The microcontroller is always in operation with the sensors and comands the flow control components of the hydraulic installation (pumps and automatic valves) following an algorithm implemented for this purpose.

The algorithm is implemented in a BASIC like language and automatically open or close the relative relay switches.

8.3 The monitoring system.

In order to obtain useful information on the system operation parameters as well as reliable evaluation of the performance, an appropriate monitoring system has been developed for this purpose.

The monitoring system is based on the Hewlett Packard 34970A data acquisition switch unit commanded by means of an algorithm developed for the purpose and implemented in an object oriented build-in language. The 34970A data acquisition unit is a 3-slot mainframe with 6 ½-digit (22-bit) internal DMM, built-in GPIB and RS-232 interfaces and having the capability to handle up to 120 single-ended measuring channels. For the purposes of this project the unit is equipped with two 34908A 40 Channel Single-Ended Multiplexer Modules and one 34901A 20 Channel Multiplexer (2/4-wire) Module

The data-logger unit is remotely commanded by a computer unit connected via HPIB interface. All the values of the system measured parameters (temperatures, flow rate) as well as meteo data values (solar radiation, ambient temperature and humidity and wind velocity and direction) are transferred and finally collected and permanently stored for further elaboration into the computer unit.

9. Commissioning and start up of the system

9.1 Filling the system

The secondary circuit where water is the heat transfer fluid, should be thoroughly flushed out with water, pressurized if necessary, and suitably isolated from the mains to prevent back siphonage.

Primary circuit using the aqueous based heat transfer fluid have to be flushed out in accordance with the fluid manufacturer's instructions. This stage of commissioning may afford an early opportunity to check that all unions and glands are watertight and free of weeps. However and, particularly in systems like the one considered here where a circulating pump is employed, the circuits will require a second inspection when finally filled and with the pump operating.

The installer should ensure that all non-return valves and the pumps are connected the right way round (usually indicated by an arrow) for the direction of flow, and that non-return valves and motorized or solenoid valves are operative.

The system should then be drained and refilled with the final charge of fluid, preferably when the collector is cold rather than hot.

It is important to ensure that air pockets are removed from sealed and vented systems, and special attention should be given to this at the time of commissioning. The design of the system allows for subsequent automatic release of air.

9.2 Electrical and auxiliary equipment

Pumps setting will have to be made to suit the flow rate required. The installer should ensure that the pump is vented of air and that it operates quietly. With the flow meter fitted to the circuit, the pump flow control should be adjusted to give the design flow rate.

Temperature sensors should be set and tested on site in accordance with the manufacturer's instructions. Correct functioning of temperature indicators should be confirmed when the system is first filled and, if possible, at a later date when the system is hot.

Correct functioning of all indicator lights and other electrical devices should be confirmed.

The manufacturer's instructions should also be followed for any frost protection equipment installed.

9.3 Thermal insulation for the system

It is recommended that all testing and inspection of the system is conducted before the system connections are thermally insulated in order to ensure that these are not weeping.

9.4 Start-up and handing over

Once the installer has completed the installation, depending upon the time of year and on the instructions of the client, the system may be either switched on and left operating, or left in a safe condition for later handingover.

In either event the installer should present to the client the appropriate documentation, according to the Standards requirements, certifying that the system has been installed and commissioned satisfactorily.

At handing-over, the client should be supplied with a user's information envelope, containing the handing-over documents, descriptive literature prepared by the designer relating to the operational principle of the system andgiving technical data on the main system components.

Warranties or guarantees issued by the manufacturers of the single components, or by the installer should be provided.

A schematic diagram of the system and a circuit diagram of the electrical controls, should be provided.

10. Operation and Maintenance of the system

The large solar thermal system considered as systems involving mechanical, hydraulic, thermal, electrical and electronic subsystems of different difficulty levels should be operated and maintained in regular basis following precise plans specified by the manufacturer and / or the consultant.

The actions to be considered can be distinguished in three levels of intervention, mainly regarding the abilities of the necessary personnel for their execution. as follows:

a) ***Surveillance level***, regarding the basic maintenance duties to be performed by the beneficiaries local service e.g. schools or hospitals technicians, keepers, etc. by verify that operational values are correct (fulfil the nominal specifications).

b) ***Preventive maintenance level***, regarding duties to be performed by the professional maintenance contractor in order to verify that performance indicators, output, protection and durability are kept within the correct operational ranges.

c) ***Supervision – Evaluation level***, regarding duties to be performed by the premise administrator or a subcontracted technical evaluator and regards the data collection and analysis, elaboration of evaluation reports etc.

Each level of operation and maintenance activities must have a plan and should be organized in categories, with respect to the subsystems given in the solar thermal system, specifying the operation to be executed as well as the frequency of the preventive actions to be taken. The different subsystems of the solar thermal system could be distinguished as those of general scope, those regarding the collectors and the roof, the piping, the thermal storage, the uses, the controls, the data logger and the processor.

In *Appendix D* a scheme for operation and maintenance of a large solar thermal system distinguished into three maintenance levels, is reported.

11. System performance prediction and evaluation

As stated by the Standard EN 12977-1 there are no requirements on system performance evaluation and monitoring for *large custom-built systems*. In this specific case the system performance prediction was carried out using the Input-Output method, developed in the Solar & Energy Systems Laboratory and reported in *Belessiotis et al. (2010)*, which is shortly described below. In order to assess the installed system performance and meanwhile validate the design method and therefore confirm the performance prediction, a long term evaluation task was executed, the results of which are also reported.

11.1 Short description of the method adopted

For any type of solar system and for a typical sunny day, the temporal evolution of the mean temperature of the working fluid in the collector field T_{Fm} and the mean storage tank temperature T_{Sm} for an initial storage water temperature T'_{Si} has the form shown in *Figure 15* below.

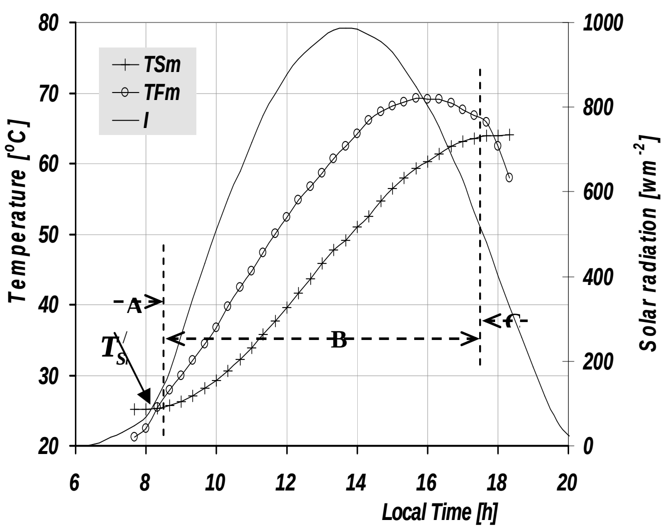


Figure 15: *Time variation of the solar radiation I, the mean storage tank temperature T_{Sm} and the mean collector-field temperature T_{Fm}, typical of a sunny day. The inertia(A), pseudo-steady state (B) and saturation (C) phases are also demarcated.*

In practice, however, the solar systems often start their daily operation at higher energy levels, due to the remaining, unused energy from the previous day. The typical development of the main energy quantities for three different days with roughly the same meteorological conditions, albeit characterized by a different temperature level of the thermal store at the start of the day, is depicted in *Figure 16* below.

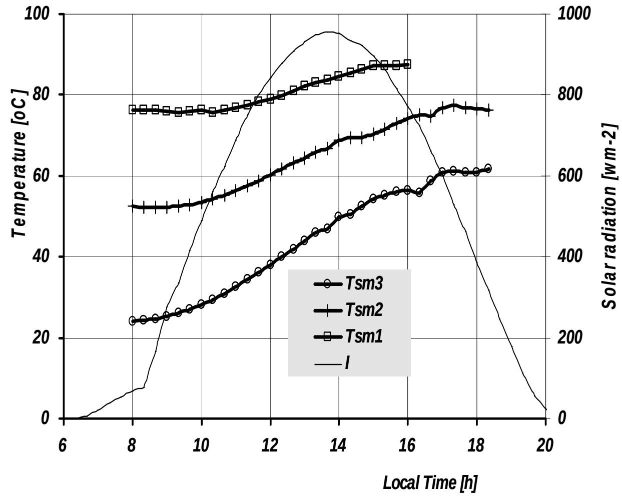


Figure 16: *Time variation of the solar radiation I and the mean tank temperature* T_{Sm} *for three different initial temperatures (*TS_{m1} *for* T_{sin}*=75°C,* TS_{m2} *for* T_{sin}*=52°C and* TS_{m3} *for* T_{sin}*=25°C, respectively)*

Upon examination of these plots, it may at first be inferred that the daily operation of such systems is characterized by the presence of three distinct phases, differing to one another with respect to the evolution of the main energetic parameters:

1. the initial inertia phase
2. the main, from the duration point of view, phase of pseudo-steady state,
3. the saturation phase.

During the *first phase*, which starts at sunrise, the system lies in a state of inertia, i.e., without any marked change in the energy content of the storage tank, but with the working fluid temperature in the collector field increasing with respect to the tank temperature. The *second phase* of pseudo-steady state, which is the longest in duration, is the phase during which practically the entire collection of solar energy and transfer to the storage tank takes place. Furthermore, during this phase the rate of change of both the mean tank water temperature T_{Sm}, as well as the mean working fluid temperature, remains almost constant. Likewise, the rate of change of the energy content of the tank water remains almost constant as well. It may, therefore, be claimed that the system lies in a pseudo-steady state from the point of view of the time variation of the energetically useful heat fluxes. The *saturation phase* originates at a time instant where $dT_{Sm}/dt \approx 0$ and is characterized by zero (or negative, if heat losses are high) net energy input to the tank.

The analytical expressions that described the instantaneous thermal behaviour of a closed-loop STS are (*Klein et al., 1974 and Duffie and Beckman, 2006*):

I. *Energy balance of the solar collector field*

$$\dot{Q}(t) + (MC)_{F-P}\frac{dT_{Fm}(t)}{dt} = A_F n_o k(t) I(t) - (AU)_{F-P}\left(T_{Fm}(t) - T_a(t)\right) \qquad (1)$$

II. *Heat transfer in the heat exchanger*

$$\dot{Q}(t) = (UA)_{ex}\left(T_{Fm}(t) - T_{sm}(t)\right) \qquad (2)$$

III. Energy balance in the storage tank

$$(MC)_s \frac{dT_{sm}(t)}{dt} = \dot{Q}(t) - (UA)_s\left(T_{sm}(t) - T_a(t)\right) \qquad (3)$$

Based on the above equation and taking into considerations the simplifications, assumptions and elaboration reported in *Belessiotis et al. (2010)*, the overall energy output Q at the end of a day which is characterized by solar energy incident on the STS equal to H_d and mean ambient temperature equal to $\bar{T}_a$, and when the initial water temperature in the storage tank is equal to T_{si}, is given by the equation:

$$Q = F_1\, H + F_2\left(\bar{T}_a - T_{si}\right) + F_3 \qquad (4)$$

with:

$$F_1 = \frac{A_F n_0 \bar{k}}{2\lambda}\left[e^{-\frac{\mu}{\lambda}t_{op}} + \left(\frac{\mu}{\lambda}\frac{t_d}{\pi}\right)\sin\left(\frac{t_{op}\pi}{t_d}\right) - \cos\left(\frac{t_{op}\pi}{t_d}\right)\right]\left[1 + \left(\frac{\mu}{\lambda}\frac{t_d}{\pi}\right)^2\right]^{-1} \qquad (4A)$$

$$F_2 = \frac{(AU)_{F-P}}{\mu}\left[e^{\frac{\mu}{\lambda}t_{op}} - 1\right] \qquad (4B)$$

$$F_3 = F_2 \frac{(MC)_F}{(MC)_s + (MC)_F}\left(T_{si} - T_a(o)\right) \qquad (4C)$$

where: $\lambda = 1 + \frac{(MC)_{F-P}}{(MC)_s} + \frac{(AU)_{F-P}}{(AU)_{ex}}$, $\mu = \frac{(AU)_{F-P}}{(MC)_s}$, $\bar{k}$ is the mean incidence angle.

From Eq. (4C) , the value of F_3 may turn out to be either positive or negative. For systems whose overall thermal capacity is much larger than that of the collector field, such as for instance inter-seasonal solar systems, the value of F_3 is practically equal to zero.

As far as the physical meaning of the coefficients of Eq. 4 is concerned, the following observations may be made regarding the coefficients involved :

- F_1, as related to the solar radiation incident on the collector field, denotes in a sense the efficiency of the system, or alternatively, the effective collector-field surface.
- F_2, as relating to the temperature difference between the tank and the surroundings, refers to the thermal losses of the system.
- F_3 expresses the thermal inertia of the system, which depends mainly on its thermal capacitance, the overall thermal losses, as well as the energy level in the storage tank at the start of the day.

It should be noted that the determination of the coefficients F_1, F_2 and F_3 always takes into account the specific characteristics of each system. Therefore, as is common practice in solar thermal system analysis, a solar collector field is treated as an equivalent collector, the characteristic data of which are determined by taking into account the respective data of each individual collector, their interconnection mode and the flow rate of the working fluid. The interconnection mode in particular affects the overall flow rate in the collector field and, consequently, the $(UA)_{ex}$ factor of the heat exchanger involved in the intermediate equations (*Duffie and Beckman, 2006*).

The application of the proposed approach in the calculation of the expected energy yield of a solar thermal system by means of Eq. 4 requires the determination of suitable values for the coefficients F_1, F_2 and F_3. From eqs. 4A, 4B, 4C it may be inferred that these coefficients are functions of the physical parameters of the solar system, the duration t_d of the day and the duration of the pseudo-steady state t_{op}, whereas, F_3 in particular, is also a function of the initial storage tank temperature T_{si}. From the same equations it may be concluded that, for each particular system, the estimation of the respective suitable coefficients ought to take into account not only the system characteristics, but also the intended conditions of its use.

11.2 Theoretical determination of the system performance

Brief technical specifications of the system are reported in the *Table 1* below while the detailed ones can be find out in *Appendix A*.

Table 1: *Technical specifications of the solar thermal system*

Quantity	Value	Units
Collector aperture area, A_c	1.78	m^2
Maximum collector efficiency, n_0	0.757	-
Overall collector heat loss coefficient, U_c	5.292	$Wm^{-2}K^{-1}$
Effective thermal capacity of collector, $(MC)_c$	16	kJK^{-1}
Water content in collector, W_w	4.5	kg
Number of collectors in the field, Nc	40	-
Heat-exchanger overall heat transfer coefficient, $(UA)_{ex}$	2500	WK^{-1}
Storage tank volume, V_s	5000	l
Overall storage-tank heat loss coefficient, $(AU)_s$	30	WK^{-1}
Initial storage tank temperature, T_{si}	35	^oC

The analytical calculation of the coefficients F_1, F_2 and F_3 was performed by means of Eqs. 4, 4A, 4B and 4C, with the efficiency figures of the collector determined according to the EN 12975-2 and ISO 9806-1 Standards and reported in *Table 10* of *Appendix A*.

Furthermore, the interconnection mode of the collectors in the field has also been considered in the calculation. For the total heat losses of the collector field, both losses from collectors and piping were taken into account. It should also be noted that constant heat losses coefficients have been considered for the storage tanks.

Based on the above, the application of the equations mentioned above, led to the theoretical estimates for the values of the coefficients shown in the *Table 2* below theoretically estimated.

Table 2: *Theoretical values of the coefficients F_1, F_2 and F_3*

Coefficient	F_1 **[m²]**	F_2 **[MJK⁻¹]**	F_3 **[MJ]**
Value of coefficient	29.8	12.2	17.5

Therefore the predicted performance for the total annual yield for the four reference cities (Athens, Davos, Stockholm, Wurzburg) is obtained:

Table 3: *Predicted results for the total annual yield for the Reference locations*

Location (latitude)	$\sum_{i=1}^{365} Q_{th,i}$ [MJ]
Stockholm (59,2^0 N)	60736
Wurzburg (49,5^0 N)	68040
Davos (46,5^0 N)	74460
Athens (38,0^0 N)	118758

11.3 Experimental determination of the system performance

For the determination of the experimental values of the coefficients F_1, F_2 *and* F_3, extensive measurements over a period of several months were performed, during which the system was subjected to diurnal operating cycles characterized by a full draw-off of the accumulated energy at the end of the day. For each day of operation, the energy supplied to the storage tank Q_{meas}, the temperature difference $(\overline{T}_a - T_{si})_{\exp}$ and the daily total incident solar radiation H at the collector level were, among other quantities, estimated.

In the following *Table 4* the compilation of measurement data used to calculate the coefficients of the system is presented.

Table 4: *Measured and elaborated data for the solar thermal system simulation*

No.	Q_{meas} [MJ]	T_a-T_{si} [K]	H [MJ/m²]	Q_{th} [MJ]	Q_{sim} [MJ]
1	548	-4,5	20,3	567	560
2	463	-3,7	16,3	458	457
3	315	-2,1	9,4	272	283
4	619	2,5	19,9	641	625
5	585	-0,8	20,6	621	609
6	597	-0,3	21,0	639	625
7	593	1,4	19,6	618	605
8	597	0,5	20,6	637	623
9	402	-2,8	15,2	436	437
10	233	-3,7	8,6	229	243
11	276	-1,0	8,8	267	278
12	475	-3,3	16,6	472	470
13	406	-5,8	15,1	397	401
14	515	-4,4	19,5	545	539
15	298	-6,1	11,7	292	303
16	248	-3,8	9,0	239	253
17	682	-5,7	24,9	690	675
18	359	-9,1	15,5	369	377
19	769	-2,6	27,2	796	773
20	360	-7,1	14,6	366	373
21	613	-1,1	20,6	618	605
22	443	-4,6	16,3	447	448
23	786	-0,7	25,6	771	749
24	663	-3,0	21,5	621	610
25	716	-2,0	23,5	693	676
26	768	-2,1	26,3	775	753
27	756	-2,5	25,7	752	732
28	781	-0,1	26,0	791	767
29	568	-0,6	18,5	561	552
30	703	0,2	23,4	717	697
31	755	2,4	23,8	755	732
32	743	0,7	24,7	762	739

No.	Q_{meas} [MJ]	T_a-T_{si} [K]	H [MJ/m²]	Q_{th} [MJ]	Q_{sim} [MJ]
33	768	0,8	24,9	769	746
34	779	2,6	25,8	817	790
35	771	3,6	24,6	794	768
36	770	3,5	25,4	816	789
37	745	1,5	25,7	801	775
38	758	3,7	24,4	789	763
39	702	-1,1	23,9	716	697
40	761	2,8	25,0	796	770
41	786	2,3	26,2	826	798
42	781	1,2	26,3	815	789
43	728	2,5	24,3	772	747
44	717	0,6	24,0	740	718
45	705	1,7	23,9	750	728
46	775	0,9	27,2	838	811
47	727	-2,3	25,8	758	737
48	741	-0,7	26,1	786	763
49	462	-1,5	16,1	479	476
50	703	0,7	22,5	696	678
51	720	-1,2	24,5	733	713
52	382	-5,8	15,4	406	410
53	549	0,1	16,9	522	515
54	618	-0,6	19,8	600	588
55	199	-6,4	7,7	169	189
56	541	0,5	17,3	539	531
57	384	-2,6	13,1	376	380
58	751	1,9	24,3	764	741
59	690	0,1	22,7	695	677
60	751	2,6	24,5	779	754
61	777	3,7	25,0	807	780
62	716	4,4	22,3	735	712
63	704	2,3	23,1	733	712
64	666	2,2	20,9	667	649

The estimation of the coefficients was achieved by means of the multi-factor least-squares method. The values computed appear on the following *Table 5*, along with the relevant statistical coefficients.

Table 5: *Experimentally obtained characteristic coefficients of the System*

Coefficient	F_1 **[m²]**	F_2 **[MJ/K]**	F_3 **[MJ]**
Value of coefficient	27.85	10.82	43.57
Standard deviation	0.57	0.99	12.64
Estimation coefficient r^2	0.98		

The predicted performance for the total annual yield for the four reference cities (Athens, Davos, Stockholm, Wurzburg) using the above calculated coefficients, is obtained and reported in the following *Table 6*:

Table 6: *Prediction results for the total annual yield for the reference locations*

Location (latitude)	$\sum_{i=1}^{365} Q_{th,i}$ **[MJ]**
Stockholm (59,2⁰ N)	64437
Wurzburg (49,5⁰ N)	71251
Davos (46,5⁰ N)	80461
Athens (38,0⁰ N)	123767

11.4 Comparison between theoretical and experimental obtained values for system performance

In *Table 7* the values of the daily energy output Q_{th} as calculated from Eq. 4 using the theoretical values of the coefficients F_1, F_2 and F_3 of Table 2, are reported. On the same table, the simulated values Q_{sim} of the daily energy output, as computed by means of Eq. 4, but making using of the values of the coefficients F_1, F_2 and F_3 as these arose from the application of the least-squares method yield from the long term monitoring, are also included.

In the *Figure 17* below the comparisons between the experimental values and the theoretical values predicted by the model for the daily output of the solar thermal system are graphically depicted, using the experimentally and theoretically derived values of the coefficients respectively.

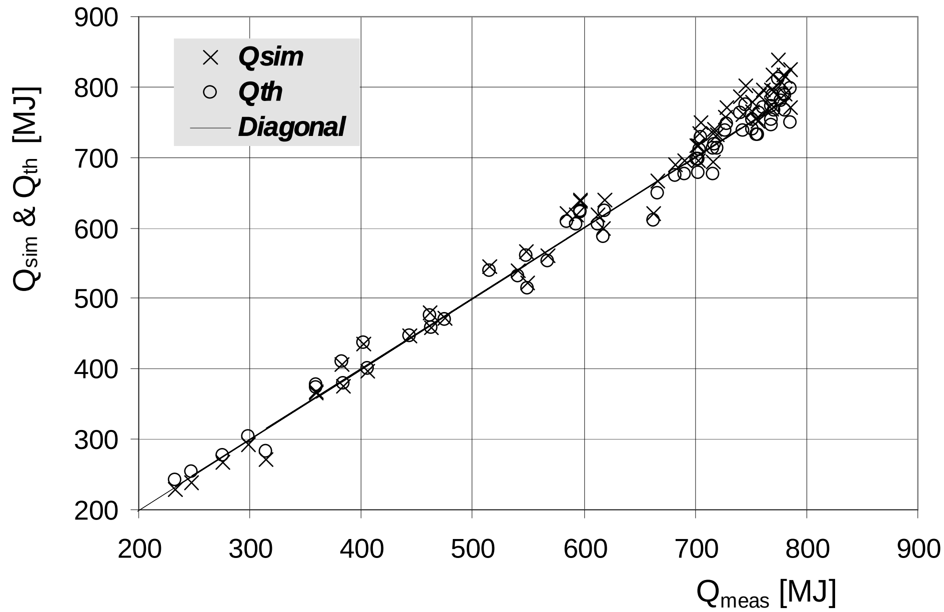


Figure 17: *Comparison of the simulated (Q_{sim}) and theoretical (Q_{th}) values of the energy output against the experimental one (Q_{meas}).*

The evaluation of the expected annual yield of the system, by comparing the results obtained using both the experimental as well as the analytically derived values of the coefficients, are also reported in *Table 7*. The evaluation was attempted by employing typical meteorological data for the four Standard locations mentioned in the Standards and reported in *Appendix E*. The daily values of the energy output $Q_{th,i}$, i=1…365 were calculated, using the theoretical values for the coefficients of *Table 2*, for all days of the year. Subsequently, the daily values $Q_{sim,i}$ were calculated using the experimentally derived values of the coefficients in *Table 5*. The results concerning the total yield comparatively shown for the entire year are presented in the *Table 7* along with the percentage difference between theoretical and experimental evaluation of the total annual yield.

Table 7: *Prediction results for the total annual yield for Standard locations*

Location (latitude)	$\sum_{i=1}^{365} Q_{th,i}$ **[MJ]**	$\sum_{i=1}^{365} Q_{sim,i}$ **[MJ]**	**Difference [%]**
Stockholm (59,2^0 N)	60736	64437	-5.7
Wuerzburg (49,5^0 N)	68040	71251	-4.5
Davos (46,5^0 N)	74460	80461	-7.5
Athens (38,0^0 N)	118758	123767	-4.0

12. Nomenclature

Symbol	Meaning	Units
A_c	Aperture area of solar collector	[m^2]
A_F	$=N_c A_c$: Total solar collector surface area	[m^2]
$(AU)_{F\text{-}P}$	Overall heat loss coefficient for collector field and piping	[WK^{-1}]
F_1	1st Coefficient of characteristic I/O equation	[m^2]
F_2	2nd Coefficient of characteristic I/O equation	[MJ/K]
F_3	3rd Coefficient of characteristic I/O equation	[MJ]
H	Daily total incident radiation at the collector level	[MJ m^{-2}]
I	Instantaneous total incident radiation at the collector level	[Wm^{-2}]
k	Incidence angle coefficient	[-]
$\bar{k}$	Mean incidence angle coefficient	[-]
$(MC)_s$	Storage tank thermal capacity	[JK^{-1}]
$(MC)_{F\text{-}p}$	Total thermal capacity of the collector field and piping	[JK^{-1}]
N_c	Number of solar collectors in the field	[-]
n_o	$=F/(\tau\alpha)_e$, Maximum instantaneous collector efficiency	[-]
Q_{meas}	Energy output of the system determined from experimental measurements	[MJ]
Q_{sim}	Energy output calculated using the experimentally determined values of the coefficients F_1, F_2 and F_3	[MJ]
Q_{th}	Energy output calculated using the theoretically derived values of the coefficients F_1, F_2 and F_3	[MJ]
$\dot{Q}(t)$	$=\dot{m}_F C_p \left(T_{Fo} - T_{Fi}\right)$: Instantaneous solar energy yield	[W]
t	Time	[s]
t_d	Duration of the day	[s]
t_{op}	Duration of the pseudo-steady state	[s]

T_a	Ambient air temperature	[^oC]
T_{Fi}	Temperature at the inlet to the collector field	[^oC]
T_{Fm}	Mean instantaneous operating temperature of collector field	[^oC]
T_{Fo}	Temperature at the outlet of the collector field	[^oC]
T_{si}	Storage tank water temperature at the start of the day	[^oC]
T_{sm}	Mean storage tank water temperature	[^oC]
U_c	$=F/U_L$ *:* Overall collector heat-loss coefficient	[$W\ m^{-2}K^{-1}$]
$(UA)_{ex}$	Overall heat transfer coefficient in the heat exchanger	[WK^{-1}]
$(UA)_s$	Overall storage-tank heat-loss coefficient	[WK^{-1}]
V_s	Volume of storage tank	[*l*]
W_w	Water content in the collector	kg

13. References

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[6] EN 12977-2, Thermal solar systems and components - Custom built systems - Part 2: Test methods for solar water heaters and combisystems.

[7] EN 12977-3, Thermal solar systems and components - Custom built systems - Part 3: Performance test methods for solar water heater stores

[8] EN 12977-4, Thermal solar systems and components - Custom built systems - Part 4: Performance test methods for solar combistores

[9] EN 12976-2, Thermal solar systems and components - Factory made systems - Part 2: Test methods

[10] EN 15316-4-3: Heating systems in buildings – Method for calculation of system energy requirements and system efficiencies – Part 4-3: Heat generation systems, thermal solar systems.

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Appendix A :

Technical specifications, testing results and SKM data sheet of the solar collector

TECHNICAL SPECIFICATIONS

Solar Collector Manufacturer : COMPANY, Type : AAA

- Gross area : 1.95 m2
- Aperture area : .... 1.78 m^2
- Absorber area : .... 1.76 m^2
- Number of covers : 1
- Cover material : .... low iron glass
- Cover thickness : .... 3 mm
- Cover transmittance : .... 0.93±0.005
- Number of riser tubes : 9
- Internal diameter of risers : .... 7 mm
- Distance between risers : .... 8 cm
- Tube material : .... Copper tubes and fins of 0.2 mm thickness
- Absorber coating : .... selective coating
- Absorptance of the absorber : .... 0.93±0.02
- Emmitance of the absorber : .... 0.14±0.001
- Tubes and fins fitting : .... ultrasonic welding
- Transfer fluid mass : .... 1.3 kg
- Insulation thickness : .... 50mm (back), 20 mm (side)

- Back insulation material : ....polyurethane foam - Rockwool

- Insulation thermal conductivity :...................................... λ= 0.03454 + 0.000162 * T[^{o}C]

- Side insulation material : ....Rockwool

- Side frame material : .... Aluminium

- Back cover material : .... Aluminium

- Gross weight of empty collector : ....34.3 kg

- Gross dimensions : .... (1980 x 985 x 100) mm

- Aperture dimensions :... (1920 x 925) mm

- Absorber dimensions : .... (1906 x 925) mm

- Sealing materials : ....EPDM – polyurethane glue

Table 8: *Measurement data*

Ημ/νία / Date	LT	G	G_d / G	t_a	u	t_{in}	(t_e-t_{in})	
H-M-E D-M-Y	Ωρες-Λεπτά h-min	W/m²	%	°C	m/s	°C	K	kg/s
30/Jul/2003	11:11-11:26	913	17	32.0	2	27.4	7.73	0.0380
30/Jul/2003	10:37-10:52	911	17	31.7	2	27.4	7.75	0.0380
31/Jul/2003	09:57-10:12	911	16	28.7	2	25.3	7.74	0.0379
31/Jul/2003	09:35-09:50	903	14	28.6	2	25.3	7.70	0.0379
31/Jul/2003	11:06-11:21	937	19	30.4	2	40.3	7.26	0.0379
30/Jul/2003	09:41-09:56	874	17	30.8	2	40.2	6.78	0.0379
31/Jul/2003	10:43-10:58	929	18	29.4	2	40.3	7.16	0.0380
30/Jul/2003	09:06-09:21	829	17	29.9	2	40.2	6.41	0.0380
29/Jul/2003	12:21-12:36	912	19	31.9	2	60.1	5.99	0.0378
29/Jul/2003	11:10-11:25	920	16	31.3	2	60.2	6.15	0.0377
30/Jul/2003	12:02-12:17	883	19	32.6	2	61.1	5.79	0.0374
30/Jul/2003	12:34-12:50	866	21	33.1	2	61.1	5.61	0.0375
30/Jul/2003	14:16-14:31	926	18	32.7	2	79.8	5.11	0.0368
29/Jul/2003	10:11-10:26	948	14	31.3	2	79.7	5.17	0.0375
29/Jul/2003	10:32-10:47	949	14	31.3	2	79.8	5.13	0.0376
30/Jul/2003	13:44-13:59	921	18	32.7	2	79.8	5.15	0.0360

Table 9: *Result data*

Ημ/νία / Date	LT	t_m	c_f	$\hat{Q}$	$(t_m - t_a)$ / G	$(t_{in} - t_a)$ / G	$\hat{Q}/(A_G G)$	$\hat{Q}/(A_c G)$	$\hat{Q}/(A_A G)$
H-M-E D-M-Y	Ωρες-Λεπτά h-min	°C	J/kg K	W	m^2 K/W	m^2 K/W	-	-	-
30/Jul/2003	11:11-11:26	31.3	4177	1227	-0.001	-0.005	0.69	0.76	0.76
30/Jul/2003	10:37-10:52	31.3	4177	1229	0.000	-0.005	0.69	0.76	0.76
31/Jul/2003	09:57-10:12	29.2	4178	1227	0.001	-0.004	0.69	0.76	0.76
31/Jul/2003	09:35-09:50	29.1	4178	1218	0.001	-0.004	0.69	0.76	0.77
31/Jul/2003	11:06-11:21	43.9	4178	1151	0.014	0.011	0.63	0.69	0.70
30/Jul/2003	09:41-09:56	43.6	4178	1075	0.015	0.011	0.63	0.69	0.70
31/Jul/2003	10:43-10:58	43.8	4178	1136	0.015	0.012	0.63	0.69	0.69
30/Jul/2003	09:06-09:21	43.4	4178	1016	0.016	0.012	0.63	0.69	0.70
29/Jul/2003	12:21-12:36	63.1	4185	947	0.034	0.031	0.53	0.58	0.59
29/Jul/2003	11:10-11:25	63.3	4185	971	0.035	0.031	0.54	0.59	0.60
30/Jul/2003	12:02-12:17	64.0	4185	907	0.036	0.032	0.53	0.58	0.58
30/Jul/2003	12:34-12:50	63.9	4185	880	0.036	0.032	0.52	0.57	0.58
30/Jul/2003	14:16-14:31	82.3	4197	788	0.054	0.051	0.44	0.48	0.48
29/Jul/2003	10:11-10:26	82.3	4197	814	0.054	0.051	0.44	0.48	0.49
29/Jul/2003	10:32-10:47	82.4	4197	809	0.054	0.051	0.44	0.48	0.48
30/Jul/2003	13:44-13:59	82.3	4197	777	0.054	0.051	0.43	0.48	0.48

Table 10: *Efficiency figures for mean temperature*

	Linear		**2nd order**		
	$\overline{\eta}_{0C}$	$\overline{U}_{C}$	$\overline{\eta}_{0C}$	$\overline{\alpha}_{1C}$	$\overline{\alpha}_{2C}$
Gross area	0.696	4.765	0.692	4.178	0.012
Aperture area	0.764	5.232	0.760	4.587	0.013
Absorber area	0.770	5.271	0.766	4.621	0.013

Figure 18: *Instantaneous efficiency curve, based on aperture area and mean temperature of heat transfer fluid*

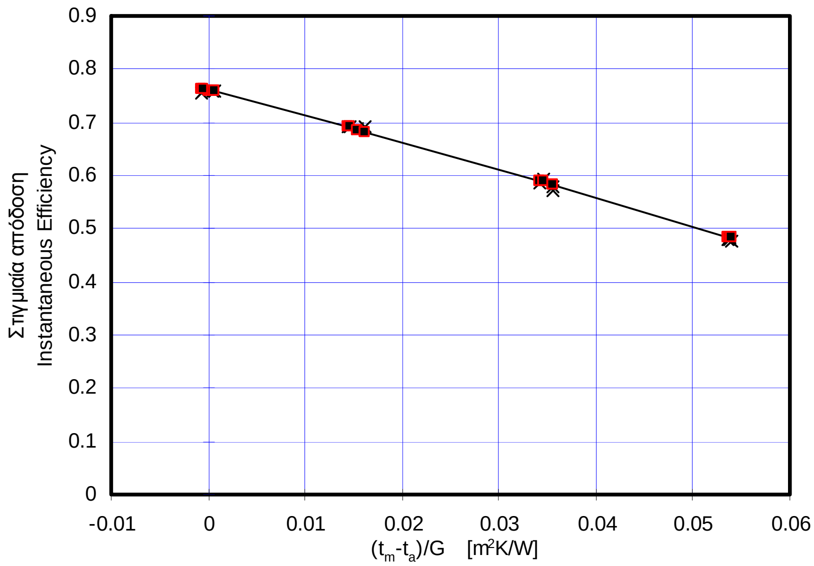

Table 11: *Power Output [W] per collector unit*

	RADIATION [W/m2]		
$(T_m\text{-}T_a)$ [K]	400	700	1000
10	456	861	1266
30	275	680	1085
50	76	481	885

Peak collector output : $\boldsymbol{W_{peak}}$ = 1665 W

Time constant : τ_c = 44 s

Effective thermal capacity : C = 15 kJ/K

Incident Angle Modifier : $k_t = -10^{-7}.x^4 + 8.(10^{-6})x^3 - 0.0002x^2 + 0.0017x + 0.9991$

C. B.

Summary of EN 12975 Test Results, annex to Solar KEYMARK Certificate Kurzfassung EN 12975 Test Ergebnisse, Anlage zum Solar KEYMARK-Zertifikat Synthèse des résultas d'essais selon EN 12975, annexe au certificat Solar KEYMARK	**Registration No.** / Registernummer / Numéro d'enregistrement: XX/XX.XX/X **Date** / Datum / Date: DD/MM/YYYY

Company / Firma / Société	COMPANY	**Country**/Land/Pays	XXXXXXXXX
Street / Straße / Rue	XXXXXXXXXXXXXX	**Website**	www.xxxxxxx.com
Postal Code, Place / PLZ, Ort / Code postal, Place	NNNNN XXXXX	**E-mail**	xxxx@xxxx.com
		Tel. / Fax	aaaa AAAAAAAAA
Collector Type / Kollektorbauart / type de capteur	Flat plate / Flachkollektor / Capteur plan		
To be roof integrated / im Dach eingegliedert zu sein / pour etre intégré dans le toit			No / nein / non

Product name Produktbezeichnung Modèle	**Aperture area** Aperturfläche Superficie d'entrée	**Gross length** Länge(Außenmaß) Longueur hors tout	**Gross width** Breite (Außenmaß) largeur hors tout	**Gross height** Höhe (Außenmaß) épaisseur hors tout	**Gross area** Bruttofläche Superficie hors-tout	**Power output per collector unit** Leistung je Kollektormodul Puissance fournie par le capteur (note 1) G = 1000 W/m² Tm-Ta: 0 K	10 K	30 K	50 K	70 K
	[m²]	[mm]	[mm]	[mm]	[m²]	[W]	[W]	[W]	[W]	[W]
AAAAAA	1.78	1,980	985	100	1.95	668	885	1,065	1,266	1,350

Collector efficiency parameters related to aperture area Kollektorleistungsparameter bezogen auf die Aperturfläche Paramètres de performances thermiques rapportées à la superficie d'entrée	(note 1)	η_{0a}	0.76	-
		a_{1a}	4.587	W/(m²K)
		a_{2a}	0.013	W/(m²K²)
Stagnation temperature / Stagnationstemperatur / Temperature de stagnation	(note 2)	t_{stg}	153	°C
Effective thermal capacity / Effektive Wärmekapazität / Capacité thermique effective		$c_{eff} = C/A_a$	8.43	kJ/(m²K)
Max. operation pressure / max. Betriebsdruck / pression d'operation de maximum	(note 3)	p_{max}	600	kPa

Incidence angle modifiers $K_\theta(\theta)$ Einfallswinkelkorrekturfaktoren $K_\theta(\theta)$ Facteur d'angle d'incidence $K_\theta(\theta)$	G_{DIF}/G_{TOT} min	max	θ_T / θ_L	50°	10°	20°	30°	40°	60°	70°
			$K_\theta(\theta_T)$	0.96	1	1	1	1	0.81	0.48
	0.15	0.31	$K_\theta(\theta_L)$	0.96	1	1	1	1	0.81	0.48
G_{DIF}/G_{TOT}: min&max while measuring / min&max während messen / min&max pendant qu'essayant					*Optional values / Angaben optional / Données optionnelles*					

Testing Laboratory / Prüflaboratorium / Laboratoire d'essais	Demokritos
Website	www.solar.demokritos.gr
Test report id. number / Prüberichtsnummer / numéro d'identification de rapport des essais	XXXXDE1, XXXXDQ1
Date of test report / Datum des Prüfberichts / date de rapport des essais	DD/MM/YYYY
Perf. test method / Leistungstestmethode / méthode d'essai de performance	EN 12975-2 6.1.4 (outdoor/außen/extérieur)

Comments of testing laboratory / Kommentare des Prüflaboratoriums / commentaires du laboratoire d'essais :

English

Deutsch

Francais

Note 1	**Test conditions** Prüfbedingungen conditions d'essais	**Fluid** Flüssigkeit Liquide	**Water** Wasser Eau	**Flow rate** Durchfluss Débit	0.020	kg/s per m²
Note 2	**Irradiance** / Bestrahlungsstärke / Irradiance G_{tt}=1000 W/m² **Ambient temperature** / Umgebungstemperatur / Temperature ambiante: t_a=30 °C					
Note 3	**Given by manufacturer** / Herstellerangaben / donnée par le fabricant					

Stamp & signature of test lab

Version 0.3.7, 05-03-2008

Figure 19: *Example of Solar Keymark Data sheet for the collector used*

Appendix B

Hydraulic connection diagram and technical specifications of the solar field

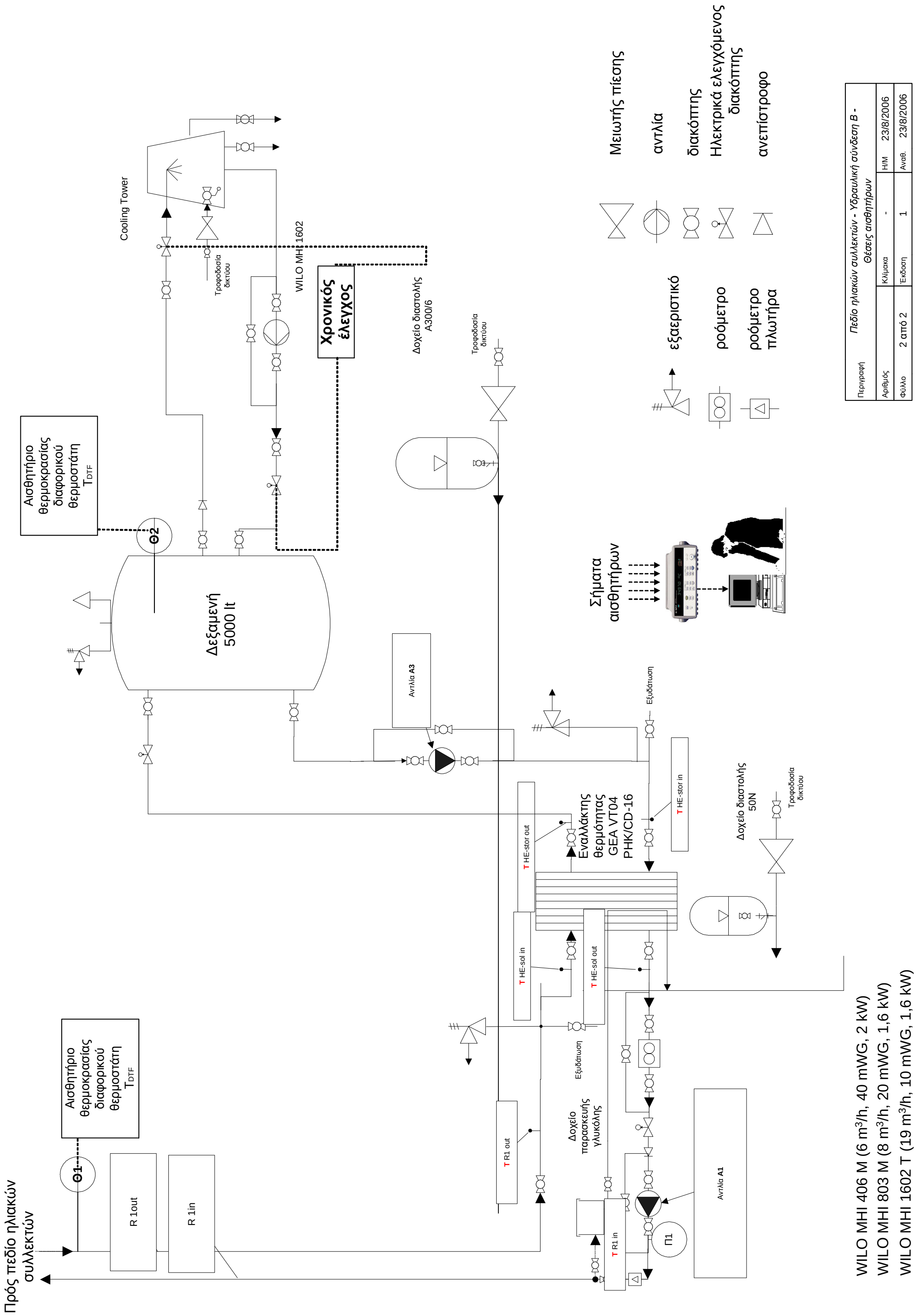

Figure 20: *Hydraulic diagram of the solar thermal system*

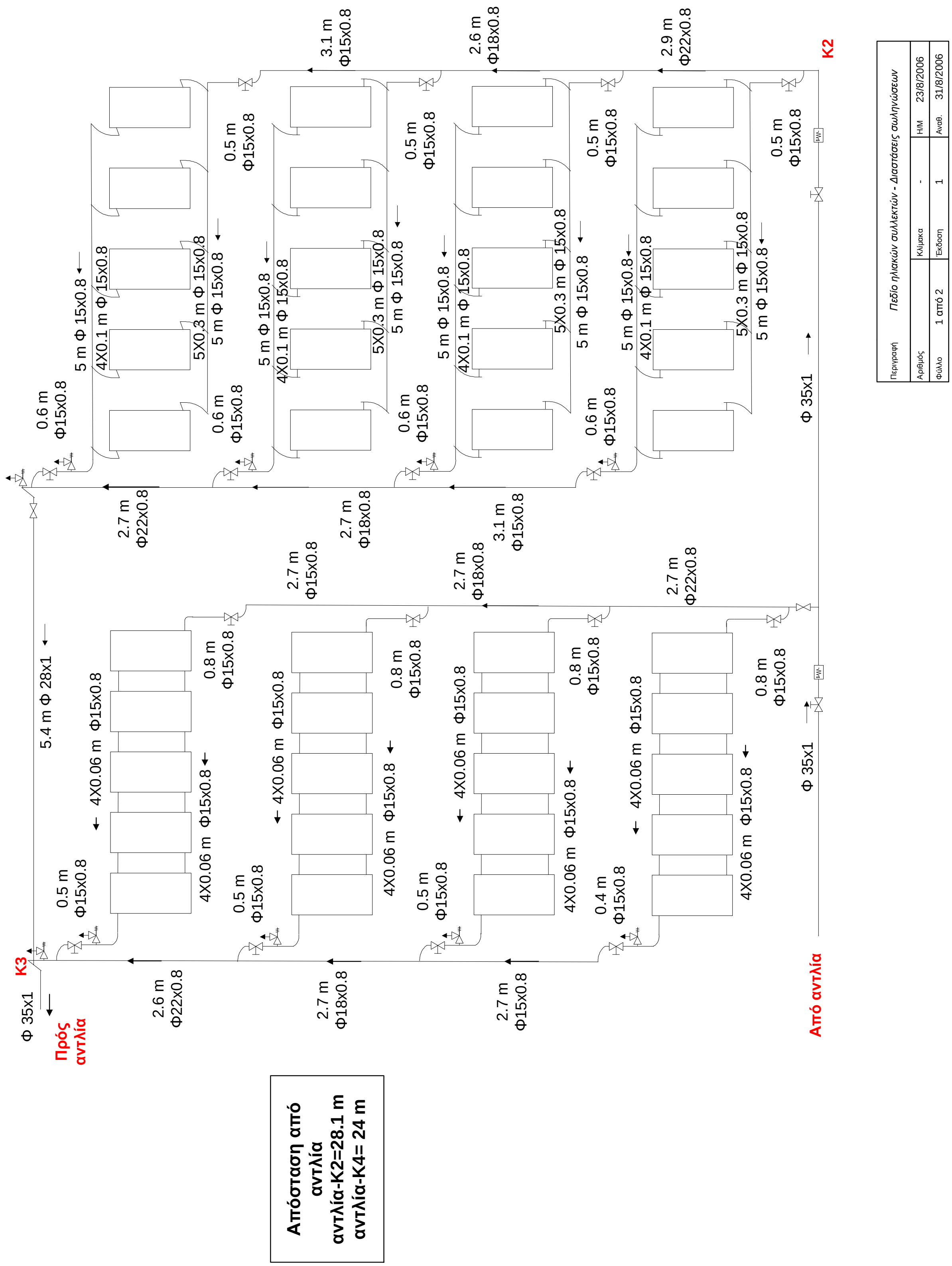

***Figure 21:** Hydraulic diagram of the solar field*

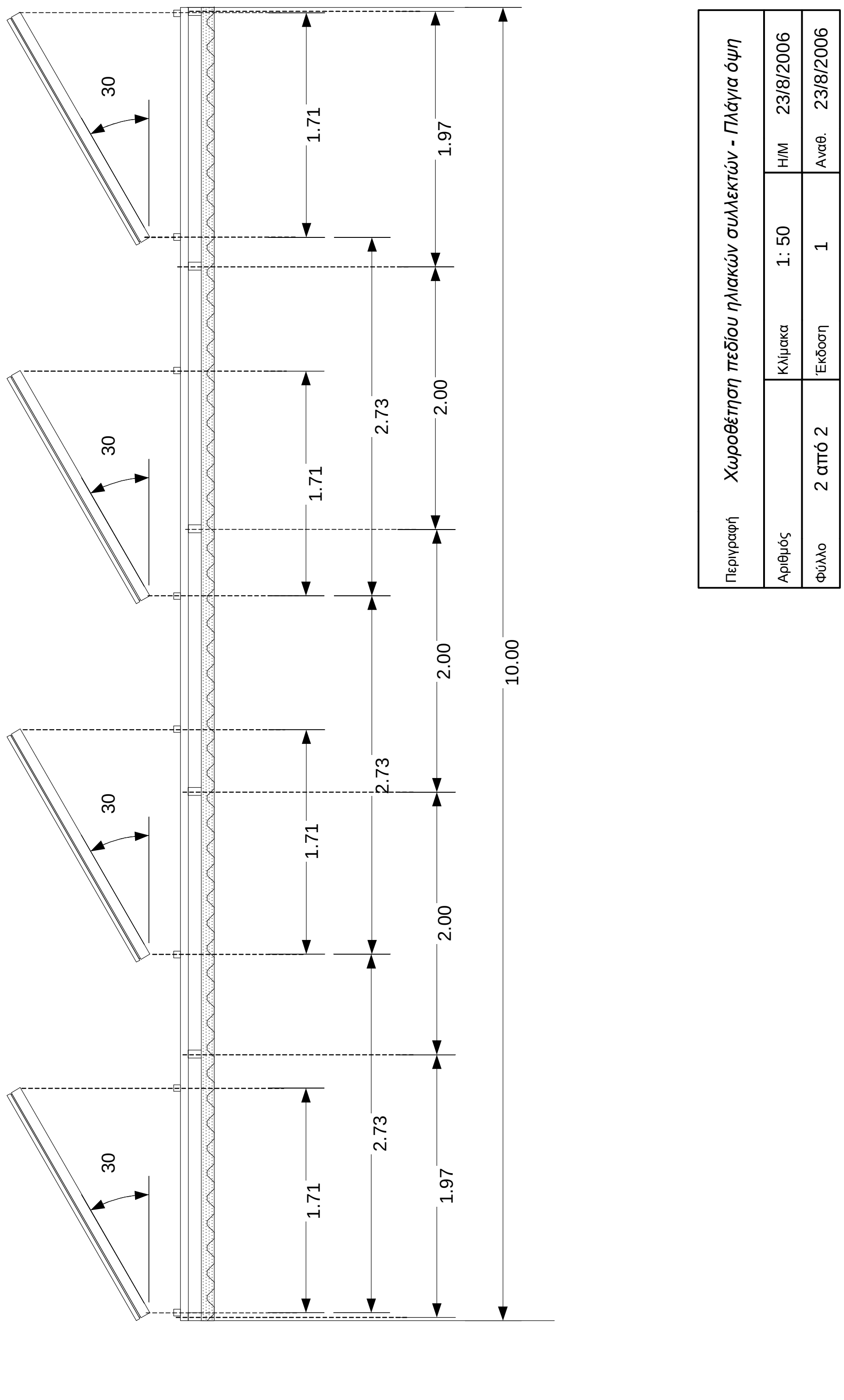

Figure 22: *Lateral view of the solar field*

Appendix C

Electrical system diagrams

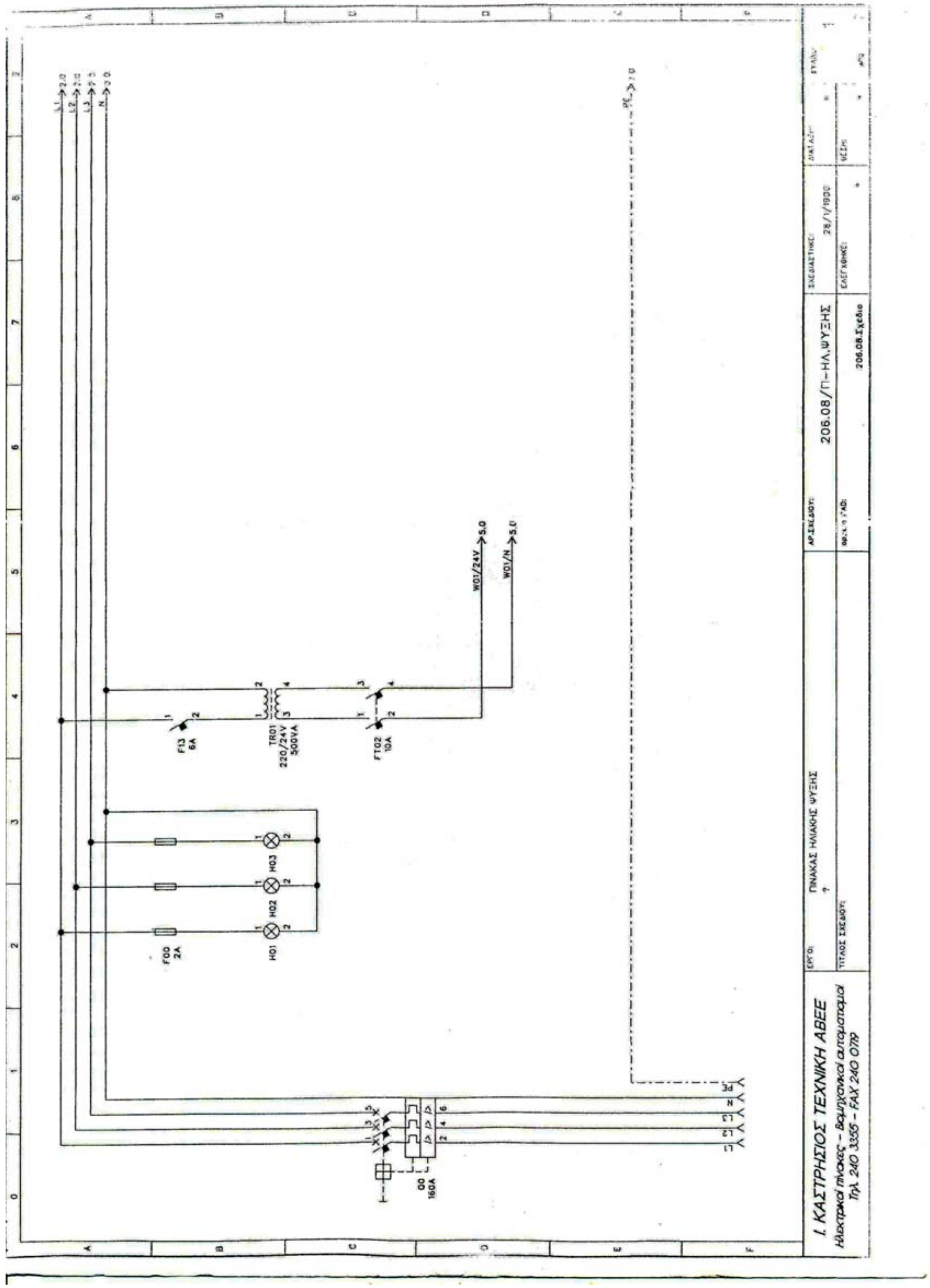

Figure 23: *Electric diagram for power and control*

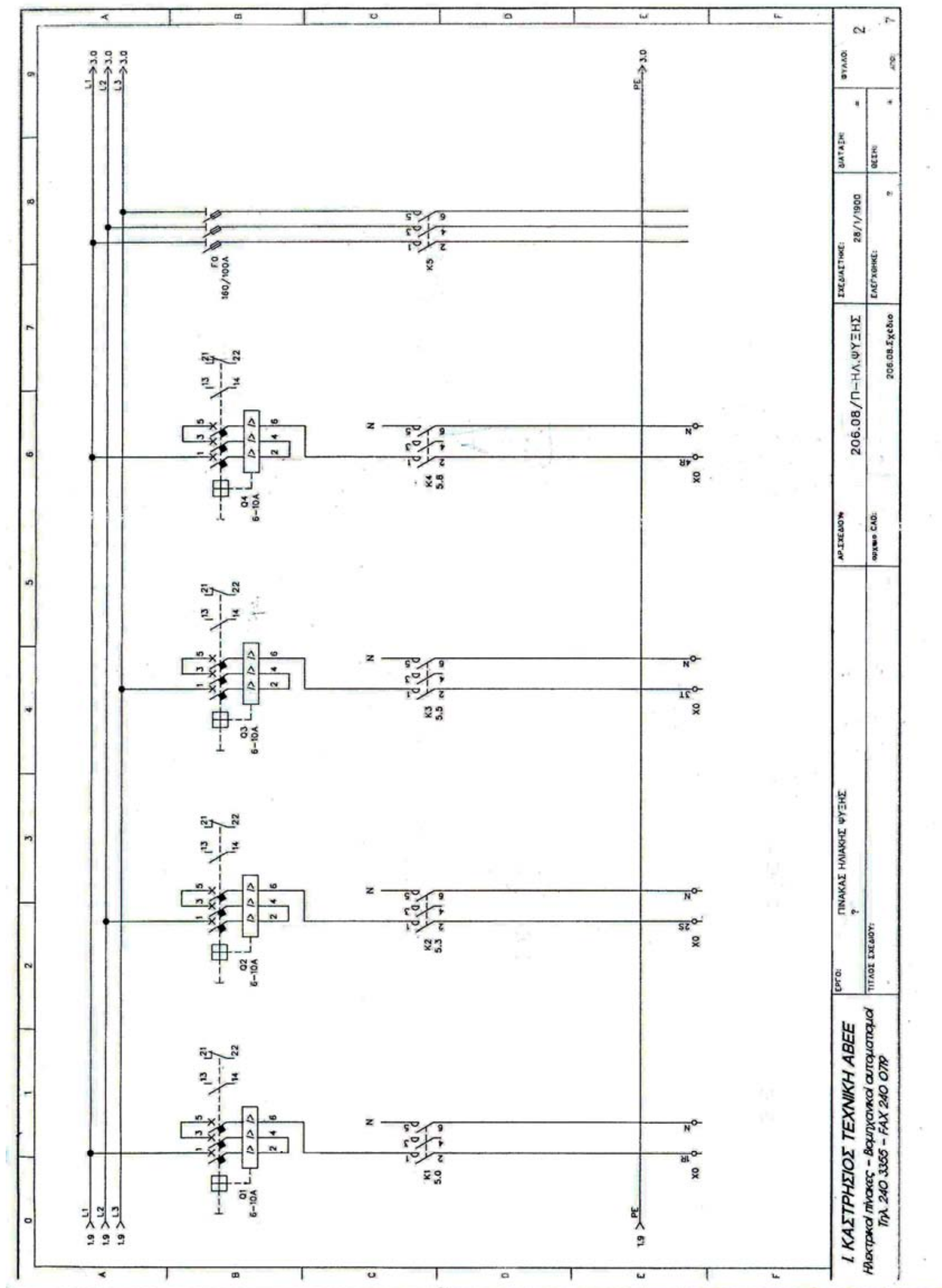

Figure 24: Electric diagram for power and control

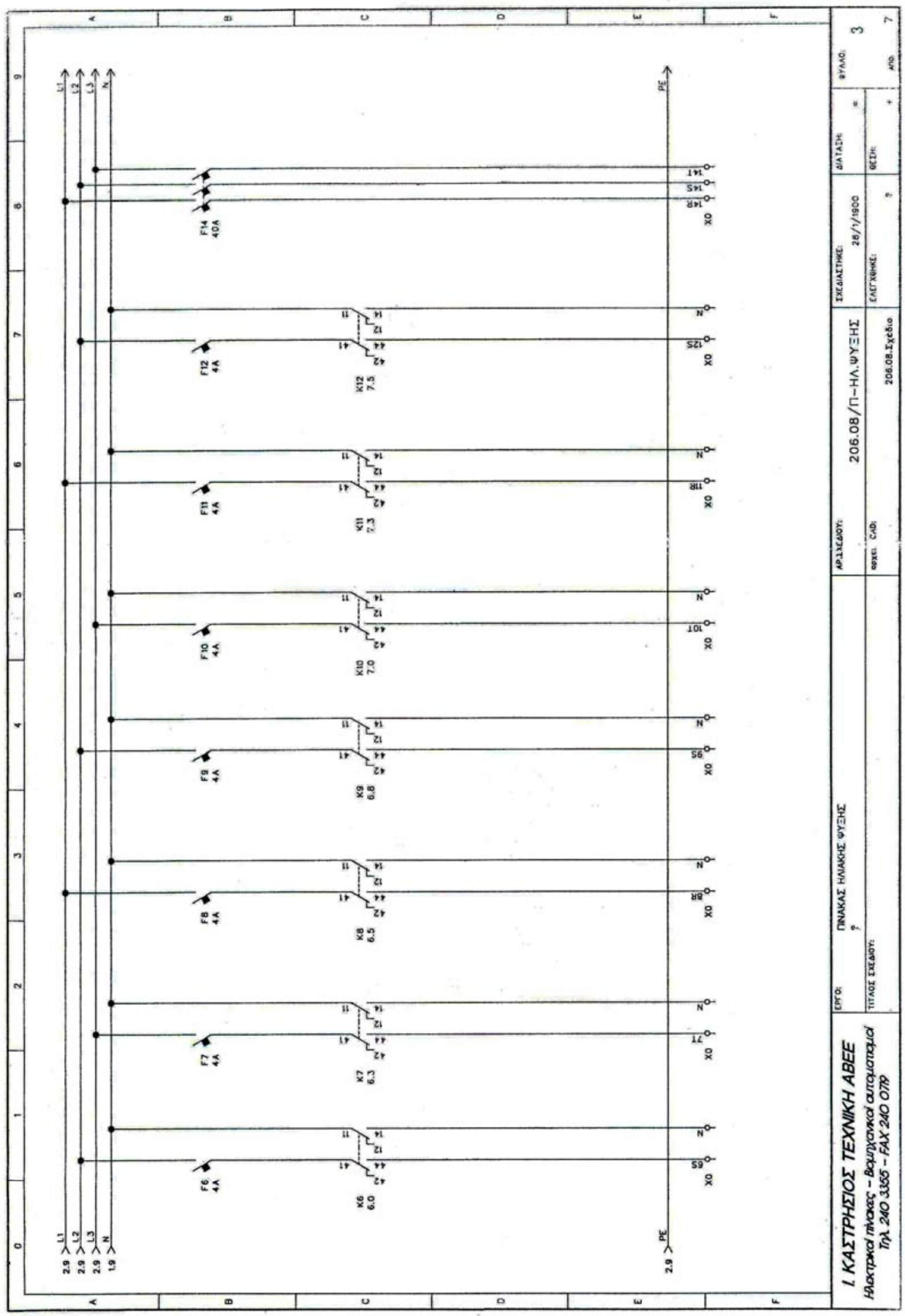

Figure 25: *Electric diagram for power and control*

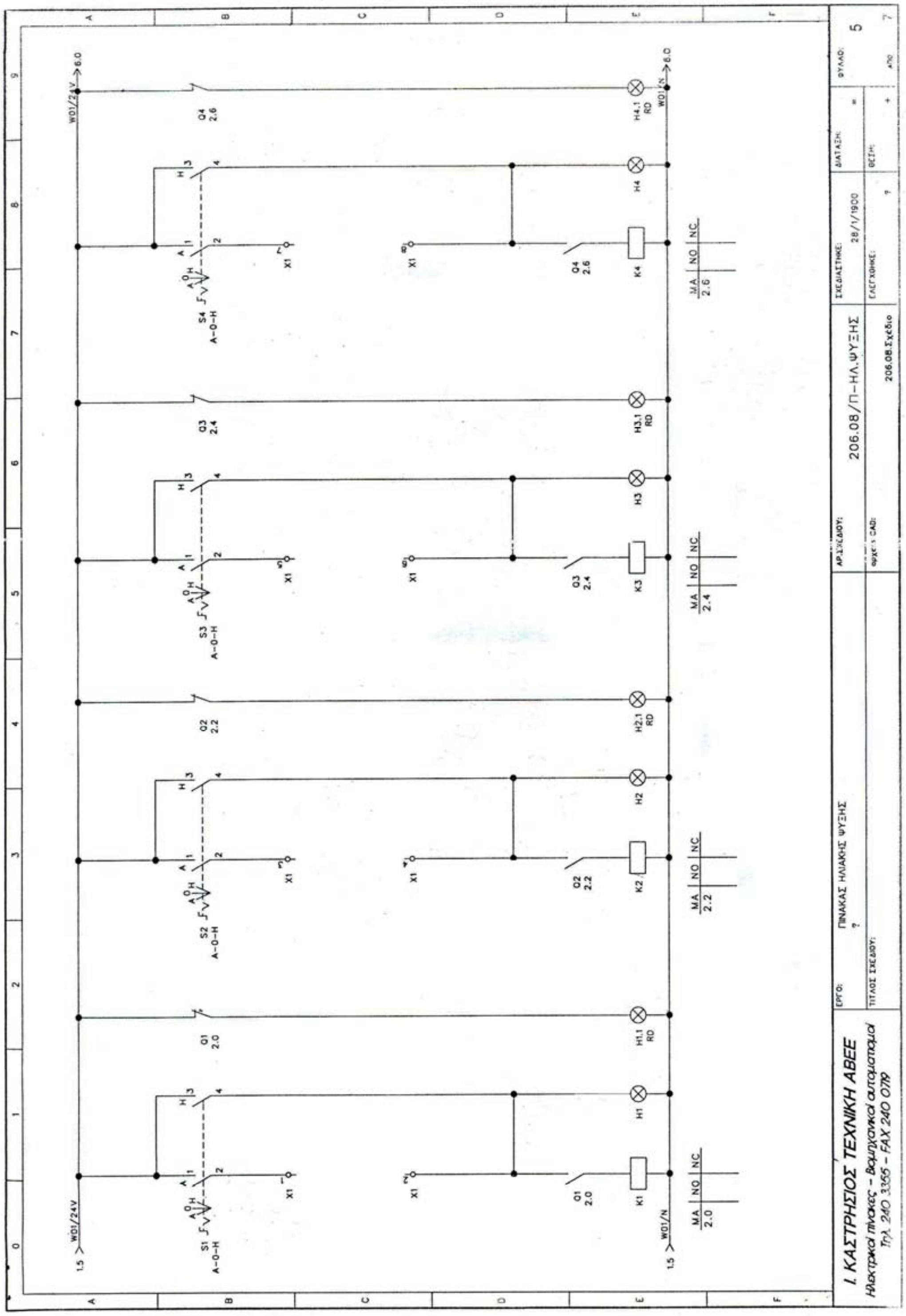

Figure 26: *Electric diagram for power and control*

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Appendix D

Operation and Maintenance scheme

1) Surveillance level

The scheme of ***surveillance level*** maintenance is organized as follows:

No	SUBSYSTEM	NAME- DESCRIPTION	Frequency
1	General	Existence and availability of O&M checklists	at all times
2	General	Existence and availability of O&M plan	at all times
3	General	Availability and updating of O&M book records (O&M book	at all times
4	General	Access to Solar Collectors arrays, HW tanks and control system rooms is restricted only to maintenance and authorised personnel	at all times
5	Solar Collectors and roof	Visual check for shading of the collectors during the day (mid-morning, noon, and mid-afternoon)	trimestral
6	Solar Collectors and roof	Prevent eventual vegetation growth that may produce shading	semestral
7	Solar Collectors and roof	Cleaning of eventual dusty or soiled collectors	trimestral
8	Solar Collectors and roof	Visual Check for condensations	monthly
9	Solar Collectors and roof	Visual Check for cracks in collector glazing	trimestral
10	Solar Collectors and roof	Visual Check condition of glazing seals - reinforce if necessary	trimestral
11	Solar Collectors and roof	Flashing and sealant around roof penetrations should be in good condition	trimestral
12	Solar Collectors and roof	Visual Check all nuts and bolts fixing the collectors to any support structures for tightness, absence of corrosion in metallic parts	trimestral
13	Solar Collectors and roof	Verify the temperature sensor condition (tight fixation, good contact, wire continuity)	trimestral
14	Solar Collectors and roof	Check the insulation protection at the collectors piping (outdoor)	trimestral
15	Hydraulics	Check for fluid leaks at pipe connections. Repair piping connections if leaking	trimestral
16	Hydraulics	Check the insulation condition (not damaged) y g) covering pipes and wiring	semestral
17	Hydraulics	Check wiring connections, should be tight	semestral
18	Hydraulics	Verify that circulation pumps are operating when conditions require it	weekly
19	Hydraulics	Verify that pressure relief valve is not	weekly

		stuck, open or closed	
20	Hydraulics	Verify the pressure gauge	weekly
21	Thermal Storage	Check thermometers in storage tanks, take temperature readings and check compliance with operating conditions	weekly
22	Thermal Storage	Check storage tanks, etc., for cracks, leaks, rust, or other signs of corrosion	trimestral
23	Data Logger and Processor	Check that basic performance parametres lie within design specifications. Register basic parameters in M&E book	weekly
24	Data Logger and Processor	Download monitoring data	monthly

2) *Preventive level*

Scheme of ***preventive level*** maintenance is organized as follows:

No	SUBSYSTEM	NAME- DESCRIPTION	Frequency
1	General	Existence and availability of as-built drawings	at all times
2	General	Existence and availability of technical documentation in English or French	at all times
3	General	Existence and availability of operations manuals in English or French	at all times
4	General	Existence and availability of the monitoring and evaluation (M&E) plan	at all times
5	General	Availability and updating of M&E reports (M&E book)	at all times
6	General	General check-up of all elements and operating conditions	yearly
7	Hydraulics	Analyse the Antifreeze solution in liquid (hydronic) solar heating collectors by a density gauge and a pH meter, and replace if necessary	yearly
8	Hydraulics	De-scaling mineral build-up in the piping and heat exchangers	yearly
9	Hydraulics	Check heat exchanger (plate, coil, insulation) for correct operation to design conditions, cleaning	yearly
10	Thermal Storage	Drain the tank to remove sediment every 3 - 4	years
11	Thermal Storage	Check the wastage of self-sacrificing anodes	yearly
12	Controls	Check control system: test differential control, thermostats, sensors	yearly
13	Controls	Check electric junction box: free of dust, tightness	yearly
14	Data Logger and Processor	Check that Operational performance parameters lie within design specifications. Register operational parameters in M&E book	monthly

3) *Supervision - evaluation level*

Scheme of ***supervision - evaluation level*** actions to be taken by the Supervisor or Consultant of the solar plant can be organized as follows:

No	SUBSYSTEM	NAME- DESCRIPTION	Frequency
1	Data Logger and Processor	Collect monitoring data, check raw data for eventual errors or inconsistencies	trimestral
2	Data Logger and Processor	Analyse monitoring data and prepare evaluation reports (semestral, yearly and aggregate). Draw conclusions and recommendations on basic and operational parameters	semestral
3	Data Logger and Processor	If 3rd level monitoring is set, Analyse Complete monitoring data, prepare evaluation reports (semestral, yearly and aggregate) and draw conclusions recommendations	semestral

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Appendix E

Reference Meteorological data

Athens

Davos

Stockholm

Wurzburg

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A. Day by Day DATA for Athens – (QAIST)

Day	H_{45} [MJ/m²]	Ta_{day} [°C]	Ta_{night} [°C]	T_{main} [°C]	Ta_d-T_{main} [°C]	T_{cold} [°C]
1	1.80	16.13	15.28	12.49	3.64	12.49
2	3.52	15.74	14.69	12.40	3.34	12.40
3	2.77	15.10	12.93	12.31	2.79	12.31
4	18.28	13.72	11.49	12.23	1.49	12.23
5	12.46	12.32	10.02	12.15	0.17	12.15
6	15.18	11.30	10.06	12.07	-0.77	12.07
7	12.77	11.78	10.41	11.99	-0.21	11.99
8	6.33	10.35	8.29	11.91	-1.56	11.91
9	16.22	10.04	8.58	11.83	-1.79	11.83
10	14.09	10.54	9.10	11.76	-1.22	11.76
11	14.74	11.38	7.98	11.68	-0.31	11.68
12	15.30	4.94	3.68	11.61	-6.67	11.61
13	12.52	8.59	7.37	11.55	-2.96	11.54
14	17.94	8.69	6.32	11.48	-2.79	11.48
15	11.21	6.13	6.48	11.41	-5.28	11.41
16	7.82	9.22	9.13	11.35	-2.13	11.35
17	3.88	10.53	9.85	11.29	-0.76	11.29
18	9.55	11.72	11.48	11.23	0.49	11.23
19	13.59	13.67	11.69	11.17	2.50	11.17
20	13.11	13.03	11.41	11.12	1.91	11.11
21	19.78	14.93	12.99	11.06	3.87	11.06
22	17.86	15.13	12.07	11.01	4.12	11.01
23	19.68	12.85	9.33	10.96	1.89	10.96
24	14.79	9.73	7.77	10.91	-1.19	10.91
25	15.47	10.28	10.35	10.87	-0.59	10.87
26	10.71	14.66	12.84	10.82	3.84	10.82
27	13.31	14.35	10.59	10.78	3.57	10.78
28	19.76	11.71	10.32	10.74	0.97	10.74
29	11.89	12.84	11.46	10.71	2.13	10.71
30	14.67	13.42	11.96	10.67	2.75	10.67
31	14.65	15.62	13.17	10.64	4.98	10.64
32	16.79	14.11	12.31	10.61	3.50	10.61
33	13.68	14.24	11.44	10.58	3.66	10.58
34	12.14	12.37	10.55	10.55	1.82	10.55
35	2.27	7.88	8.28	10.53	-2.65	10.53
36	2.96	11.36	10.73	10.50	0.86	10.50
37	0.51	9.40	8.20	10.48	-1.08	10.48
38	18.51	11.23	9.14	10.47	0.76	10.47
39	5.48	7.70	6.90	10.45	-2.75	10.45
40	7.75	7.91	6.54	10.44	-2.53	10.44
41	16.21	9.69	8.70	10.42	-0.73	10.42
42	6.89	9.76	8.44	10.42	-0.66	10.42
43	7.54	9.42	9.56	10.41	-0.99	10.41
44	3.36	12.15	9.05	10.40	1.75	10.40
45	8.59	6.58	4.39	10.40	-3.82	10.40
46	12.19	7.64	7.66	10.40	-2.76	10.40
47	14.82	11.52	10.23	10.40	1.12	10.40
48	16.38	13.31	9.74	10.41	2.90	10.41
49	21.72	10.84	8.79	10.41	0.43	10.41
50	21.43	12.29	10.53	10.42	1.87	10.42
51	21.04	13.61	12.33	10.43	3.18	10.43

52	20.74	16.16	14.42	10.44	5.72	10.44
53	19.47	16.72	14.20	10.46	6.26	10.46
54	9.15	13.27	10.60	10.47	2.80	10.47
55	17.99	14.48	11.07	10.49	3.99	10.49
56	23.02	13.78	10.23	10.51	3.27	10.51
57	21.95	12.89	11.02	10.54	2.35	10.54
58	19.80	15.14	13.63	10.56	4.58	10.56
59	10.89	15.18	12.21	10.59	4.59	10.59
60	16.35	12.68	10.23	10.62	2.06	10.62
61	17.13	12.49	9.72	10.65	1.84	10.65
62	15.55	9.88	7.18	10.69	-0.82	10.69
63	13.16	8.61	7.98	10.72	-2.11	10.72
64	7.77	10.25	9.88	10.76	-0.51	10.76
65	2.46	10.78	9.16	10.80	-0.02	10.80
66	17.05	11.35	7.81	10.85	0.50	10.85
67	24.71	7.48	4.56	10.89	-3.42	10.89
68	22.13	8.67	6.24	10.94	-2.27	10.94
69	22.54	9.78	8.06	10.98	-1.20	10.98
70	21.10	12.23	10.90	11.04	1.19	11.04
71	3.22	9.93	9.45	11.09	-1.16	11.09
72	6.00	12.07	10.01	11.14	0.93	11.14
73	16.98	12.89	12.80	11.20	1.69	11.20
74	6.69	13.92	11.63	11.26	2.66	11.26
75	19.98	15.58	14.93	11.32	4.26	11.32
76	13.36	19.07	16.40	11.38	7.69	11.38
77	8.88	16.31	14.68	11.45	4.86	11.45
78	3.47	15.49	13.11	11.51	3.98	11.51
79	9.50	13.03	11.34	11.58	1.45	11.58
80	8.14	13.88	11.33	11.65	2.23	11.65
81	20.75	16.42	13.99	11.72	4.70	11.72
82	9.00	14.45	12.34	11.79	2.66	11.79
83	17.14	15.62	12.04	11.87	3.75	11.87
84	21.05	15.20	11.82	11.95	3.25	11.95
85	19.68	14.53	11.90	12.03	2.50	12.03
86	22.59	17.33	14.88	12.11	5.22	12.11
87	9.44	16.11	13.72	12.19	3.92	12.19
88	6.71	14.00	12.26	12.27	1.73	12.27
89	13.11	16.12	13.03	12.36	3.76	12.36
90	23.42	18.52	13.19	12.45	6.07	12.45
91	25.15	11.98	9.85	12.53	-0.56	12.53
92	18.31	13.52	10.06	12.62	0.90	12.62
93	18.39	11.38	9.18	12.72	-1.35	12.72
94	20.75	14.10	12.00	12.81	1.29	12.81
95	22.00	16.25	13.38	12.90	3.35	12.90
96	22.02	15.78	14.58	13.00	2.78	13.00
97	14.28	18.38	15.34	13.10	5.28	13.10
98	21.14	17.79	14.37	13.20	4.59	13.20
99	17.34	16.81	15.66	13.30	3.51	13.30
100	11.97	19.79	18.27	13.40	6.39	13.40
101	15.67	20.73	16.83	13.50	7.23	13.50
102	20.39	18.06	14.34	13.61	4.45	13.61
103	17.09	16.29	13.70	13.71	2.58	13.71
104	12.28	16.08	12.04	13.82	2.26	13.82
105	22.46	15.66	11.98	13.93	1.73	13.93
106	25.01	15.08	12.66	14.04	1.04	14.04

107	24.94	18.06	12.94	14.15	3.91	14.15
108	25.00	15.03	11.18	14.26	0.77	14.26
109	18.87	14.50	11.39	14.37	0.13	14.37
110	20.82	15.48	13.78	14.48	1.00	14.48
111	3.94	14.73	12.81	14.60	0.13	14.60
112	20.45	17.15	14.77	14.71	2.44	14.71
113	19.52	19.59	15.08	14.83	4.76	14.83
114	18.39	16.93	15.73	14.95	1.98	14.95
115	14.00	19.50	18.16	15.06	4.44	15.06
116	10.66	19.11	16.49	15.18	3.93	15.18
117	19.43	21.18	16.72	15.30	5.88	15.30
118	20.77	19.71	15.88	15.42	4.29	15.42
119	9.72	16.13	13.27	15.54	0.59	15.54
120	10.70	16.13	15.56	15.67	0.46	15.67
121	15.84	20.60	17.88	15.79	4.81	15.79
122	17.95	21.35	19.87	15.91	5.44	15.91
123	7.97	21.14	18.19	16.03	5.11	16.03
124	24.73	21.66	18.13	16.16	5.50	16.16
125	24.13	23.23	20.18	16.28	6.95	16.28
126	17.33	22.78	20.58	16.41	6.37	16.41
127	3.02	19.21	16.81	16.53	2.68	16.53
128	18.55	19.11	15.82	16.66	2.45	16.66
129	15.33	18.16	14.93	16.78	1.38	16.78
130	16.61	17.58	15.33	16.91	0.67	16.91
131	20.92	19.73	16.83	17.04	2.69	17.04
132	8.06	15.90	13.08	17.16	-1.26	17.16
133	21.57	19.22	16.21	17.29	1.93	17.29
134	13.28	16.39	16.83	17.42	-1.03	17.42
13	7.20	20.46	17.61	17.55	2.91	11.54
136	18.69	19.88	17.03	17.67	2.21	17.67
137	19.27	20.03	16.21	17.80	2.23	17.80
138	22.36	19.68	16.74	17.93	1.75	17.93
139	21.50	20.87	20.16	18.05	2.82	18.05
140	21.55	27.14	22.24	18.18	8.96	18.18
141	24.36	25.56	20.53	18.31	7.25	18.31
142	24.63	24.71	20.39	18.44	6.27	18.44
143	24.62	25.16	19.68	18.56	6.60	18.56
144	24.70	23.10	19.11	18.69	4.41	18.69
145	23.76	23.71	20.13	18.82	4.89	18.82
146	23.19	24.29	20.50	18.94	5.35	18.94
147	23.39	25.14	22.78	19.07	6.07	19.07
148	11.15	24.82	21.54	19.19	5.63	19.19
149	23.85	23.90	18.98	19.32	4.58	19.32
150	23.37	22.35	18.10	19.44	2.91	19.44
151	23.70	22.81	19.59	19.57	3.24	19.57
152	24.13	24.59	22.92	19.69	4.90	19.69
153	5.53	23.89	22.13	19.81	4.08	19.81
154	11.52	24.20	19.83	19.93	4.27	19.93
155	21.56	21.31	19.13	20.06	1.25	20.06
156	14.67	23.88	19.98	20.18	3.70	20.18
157	23.70	23.23	19.32	20.30	2.93	20.30
158	23.31	23.57	19.40	20.42	3.15	20.42
159	22.92	22.28	19.38	20.54	1.74	20.54
160	19.04	23.97	20.28	20.65	3.32	20.65
161	22.10	24.97	20.94	20.77	4.20	20.77

162	23.63	25.60	21.98	20.89	4.71	20.89
163	21.69	25.68	21.58	21.00	4.68	21.00
164	22.60	25.22	21.42	21.12	4.10	21.12
165	22.85	26.18	22.23	21.23	4.95	21.23
166	22.83	26.70	22.28	21.34	5.36	21.34
167	22.98	26.37	22.43	21.45	4.92	21.45
168	22.64	26.83	22.85	21.56	5.27	21.56
169	20.16	25.51	24.57	21.67	3.84	21.67
170	20.16	30.98	26.96	21.78	9.20	21.78
171	19.34	29.23	24.95	21.89	7.34	21.89
172	19.78	28.16	24.03	21.99	6.17	21.99
173	22.38	27.84	24.84	22.10	5.74	22.10
174	18.19	28.92	24.78	22.20	6.72	22.20
175	22.97	28.87	25.16	22.30	6.57	22.30
176	23.04	30.70	24.95	22.40	8.30	22.40
177	21.08	26.59	22.97	22.50	4.09	22.50
178	20.68	26.35	22.63	22.60	3.75	22.60
179	18.52	25.33	21.00	22.70	2.63	22.70
180	22.41	24.58	22.44	22.79	1.79	22.79
181	18.08	27.01	24.35	22.88	4.13	22.88
182	22.16	28.44	26.27	22.98	5.46	22.98
183	13.74	29.13	25.88	23.07	6.06	23.07
184	21.50	29.88	26.06	23.15	6.73	23.15
185	16.49	27.23	24.20	23.24	3.99	23.24
186	16.86	27.41	23.68	23.33	4.08	23.33
187	23.75	26.83	23.98	23.41	3.42	23.41
188	21.14	28.15	25.25	23.49	4.66	23.49
189	22.46	29.79	27.09	23.57	6.22	23.57
190	22.06	32.03	27.48	23.65	8.38	23.65
191	22.72	29.99	26.37	23.73	6.26	23.73
192	21.54	29.34	25.58	23.81	5.53	23.81
193	22.46	29.19	25.79	23.88	5.31	23.88
194	19.64	29.30	24.23	23.95	5.35	23.95
195	21.64	26.17	22.24	24.02	2.15	24.02
196	24.17	25.78	22.52	24.09	1.69	24.09
197	22.80	27.20	24.03	24.15	3.05	24.15
198	24.27	28.29	25.84	24.22	4.07	24.22
199	23.03	30.52	27.56	24.28	6.24	24.28
200	19.48	30.09	26.63	24.34	5.75	24.34
201	17.68	27.33	26.26	24.40	2.93	24.40
202	23.47	33.63	29.75	24.46	9.17	24.46
203	23.46	32.61	28.03	24.51	8.10	24.51
204	23.83	31.19	27.02	24.56	6.63	24.56
205	24.27	30.46	25.83	24.62	5.84	24.62
206	24.72	28.68	24.48	24.66	4.02	24.66
207	23.25	27.33	24.53	24.71	2.62	24.71
208	21.74	28.78	26.35	24.75	4.03	24.75
209	19.85	29.97	26.81	24.80	5.17	24.80
210	23.92	31.71	27.12	24.84	6.87	24.84
211	22.02	28.29	25.93	24.88	3.41	24.88
212	23.73	31.16	26.04	24.91	6.25	24.91
213	24.86	28.65	24.15	24.95	3.70	24.95
214	23.79	28.22	23.82	24.98	3.24	24.98
215	21.59	26.87	22.74	25.01	1.86	25.01
216	18.80	24.63	22.88	25.04	-0.41	25.04

217	21.89	27.47	23.98	25.06	2.41	25.06
218	20.18	26.93	22.80	25.09	1.84	25.09
219	22.16	25.98	23.38	25.11	0.87	25.11
220	23.33	27.63	23.83	25.13	2.50	25.13
221	23.19	26.68	24.08	25.14	1.54	25.14
222	23.23	28.22	25.48	25.16	3.06	25.16
223	24.09	30.10	26.61	25.17	4.93	25.17
224	24.75	30.54	26.03	25.18	5.36	25.18
225	24.26	28.33	25.98	25.19	3.14	25.19
226	22.95	30.82	26.46	25.19	5.63	25.19
227	23.27	29.11	25.26	25.20	3.91	25.20
228	23.34	28.64	26.34	25.20	3.44	25.20
229	24.45	31.48	28.90	25.20	6.28	25.20
230	23.00	32.84	29.60	25.20	7.64	25.20
231	23.16	33.53	29.48	25.19	8.34	25.19
232	23.75	31.61	27.33	25.18	6.43	25.18
233	23.26	29.56	25.36	25.18	4.38	25.18
234	24.03	27.58	24.40	25.16	2.42	25.16
235	19.52	27.98	24.81	25.15	2.83	25.15
236	23.32	28.80	26.63	25.13	3.67	25.13
237	23.35	31.07	27.51	25.12	5.95	25.12
238	21.77	29.13	26.69	25.10	4.03	25.10
239	20.04	30.72	27.58	25.07	5.65	25.07
240	24.92	30.78	26.51	25.05	5.73	25.05
241	25.37	29.20	26.30	25.02	4.18	25.02
242	21.68	29.88	27.64	24.99	4.89	24.99
243	24.78	32.28	27.17	24.96	7.32	24.96
244	21.26	28.23	24.61	24.93	3.30	24.93
245	23.05	28.97	25.41	24.89	4.08	24.89
246	21.16	28.78	26.23	24.86	3.92	24.86
247	22.88	30.12	27.33	24.82	5.30	24.82
248	17.58	29.18	25.43	24.78	4.40	24.78
249	25.71	28.42	23.04	24.73	3.69	24.73
250	24.46	24.48	21.79	24.69	-0.21	24.69
251	22.89	26.71	22.38	24.64	2.07	24.64
252	24.16	24.63	20.88	24.59	0.04	24.59
253	25.47	24.68	20.30	24.54	0.14	24.54
254	21.70	21.98	18.96	24.48	-2.51	24.49
255	23.60	23.56	20.18	24.43	-0.87	24.43
256	25.76	23.88	21.98	24.37	-0.50	24.37
257	24.73	27.56	23.76	24.31	3.25	24.31
258	22.32	25.64	22.77	24.25	1.39	24.25
259	18.44	25.39	20.96	24.19	1.20	24.19
260	14.63	20.54	20.51	24.12	-3.58	24.12
261	15.86	26.59	23.45	24.05	2.54	24.06
262	25.10	25.10	21.78	23.99	1.11	23.99
263	23.61	24.88	22.54	23.92	0.95	23.92
264	24.91	26.44	23.37	23.84	2.60	23.84
265	14.91	24.02	22.26	23.77	0.25	23.77
266	14.38	24.09	23.43	23.69	0.40	23.69
267	22.34	27.60	24.42	23.61	3.99	23.61
268	22.61	26.35	23.50	23.53	2.82	23.53
269	20.79	25.38	22.42	23.45	1.93	23.45
270	25.37	25.58	21.35	23.37	2.21	23.37
271	21.71	21.98	21.45	23.29	-1.32	23.29

272	18.21	26.18	23.24	23.20	2.98	23.20
273	23.90	26.08	20.36	23.11	2.97	23.11
274	22.74	21.66	17.43	23.02	-1.36	23.02
275	22.36	20.46	18.11	22.93	-2.47	22.93
276	14.93	20.83	18.11	22.84	-2.01	22.84
277	23.30	22.67	19.88	22.74	-0.07	22.74
278	18.31	23.25	20.27	22.65	0.60	22.65
279	19.54	23.23	22.87	22.55	0.68	22.55
280	5.37	23.79	21.74	22.45	1.34	22.45
281	6.13	21.44	20.11	22.35	-0.91	22.35
282	18.36	24.63	21.48	22.25	2.38	22.25
283	22.71	26.10	23.86	22.15	3.95	22.15
284	13.19	26.27	22.53	22.05	4.22	22.05
285	21.19	25.78	22.08	21.94	3.84	21.94
286	21.33	25.37	21.31	21.83	3.54	21.84
287	23.62	24.15	20.73	21.73	2.42	21.73
288	16.93	23.55	19.35	21.62	1.93	21.62
289	15.60	20.45	17.58	21.51	-1.06	21.51
290	22.61	22.49	19.02	21.40	1.09	21.40
291	22.95	21.94	18.15	21.29	0.65	21.29
292	17.90	19.69	19.12	21.17	-1.48	21.17
293	5.07	22.31	19.77	21.06	1.25	21.06
294	19.03	20.93	17.70	20.95	-0.02	20.95
295	15.49	19.38	17.77	20.83	-1.46	20.83
296	5.06	18.28	16.90	20.71	-2.44	20.71
297	11.40	19.21	16.48	20.60	-1.39	20.60
298	13.51	18.25	14.98	20.48	-2.23	20.48
299	12.55	14.59	12.80	20.36	-5.77	20.36
300	20.34	16.93	14.13	20.24	-3.31	20.24
301	21.06	14.01	12.60	20.12	-6.11	20.12
302	17.69	17.77	16.66	20.00	-2.23	20.00
303	12.94	18.49	15.35	19.87	-1.38	19.87
304	16.37	15.83	11.33	19.75	-3.92	19.75
305	17.68	9.99	7.27	19.63	-9.64	19.63
306	13.91	11.90	10.48	19.50	-7.60	19.50
307	9.14	13.70	11.98	19.38	-5.68	19.38
308	8.81	14.07	11.57	19.26	-5.19	19.26
309	14.97	14.99	12.39	19.13	-4.14	19.13
310	19.05	15.28	12.98	19.00	-3.73	19.01
311	20.34	16.21	14.49	18.88	-2.67	18.88
312	20.43	18.03	17.74	18.75	-0.72	18.75
313	5.70	19.81	18.77	18.63	1.18	18.63
314	5.97	20.58	19.43	18.50	2.08	18.50
315	9.32	22.38	18.64	18.37	4.01	18.37
316	9.37	18.10	14.89	18.25	-0.15	18.25
317	11.80	15.49	14.68	18.12	-2.63	18.12
318	12.24	16.59	13.83	17.99	-1.40	17.99
319	15.92	15.65	13.86	17.86	-2.21	17.86
320	20.12	17.63	15.45	17.74	-0.11	17.74
321	14.58	16.96	14.77	17.61	-0.65	17.61
322	11.70	16.13	16.67	17.48	-1.35	17.48
323	12.59	22.03	19.09	17.35	4.68	17.36
324	20.16	20.40	18.60	17.23	3.17	17.23
325	3.49	18.18	16.65	17.10	1.08	17.10
326	9.32	18.88	18.09	16.97	1.91	16.97

327	9.25	19.75	16.01	16.85	2.90	16.85
328	7.20	14.46	13.95	16.72	-2.26	16.72
329	8.72	17.54	15.90	16.60	0.94	16.60
330	4.61	16.40	14.97	16.47	-0.07	16.47
331	7.52	16.17	13.26	16.34	-0.17	16.35
332	10.39	14.08	11.64	16.22	-2.15	16.22
333	10.21	12.42	10.47	16.10	-3.68	16.10
334	16.96	13.07	11.59	15.97	-2.90	15.97
335	17.93	15.07	11.41	15.85	-0.78	15.85
336	15.74	10.84	11.15	15.73	-4.89	15.73
337	16.95	17.29	15.73	15.60	1.69	15.61
338	14.67	17.26	14.23	15.48	1.78	15.48
339	6.93	13.49	12.33	15.36	-1.87	15.36
340	5.09	12.81	11.85	15.24	-2.43	15.24
341	13.00	14.78	14.15	15.12	-0.34	15.12
342	3.84	14.83	12.97	15.00	-0.18	15.01
343	1.98	11.99	12.10	14.89	-2.90	14.89
344	0.78	13.13	11.66	14.77	-1.64	14.77
345	2.10	8.98	7.67	14.65	-5.67	14.66
346	16.90	13.23	11.00	14.54	-1.32	14.54
347	13.47	11.40	11.20	14.43	-3.03	14.43
348	9.74	16.03	14.23	14.31	1.72	14.31
349	15.32	16.17	15.27	14.20	1.97	14.20
350	12.30	18.48	16.68	14.09	4.39	14.09
351	3.61	14.97	14.41	13.98	0.99	13.98
352	14.27	18.88	17.77	13.87	5.01	13.87
353	11.69	17.51	15.03	13.77	3.74	13.77
354	16.91	17.92	13.22	13.66	4.26	13.66
355	9.76	9.37	10.28	13.55	-4.18	13.55
356	8.42	16.48	14.15	13.45	3.03	13.45
357	8.32	11.60	7.93	13.35	-1.75	13.35
358	11.92	7.97	5.60	13.25	-5.28	13.25
359	15.71	7.36	6.36	13.15	-5.79	13.15
360	7.54	8.44	7.83	13.05	-4.61	13.05
361	7.83	8.92	8.31	12.95	-4.03	12.95
362	9.37	10.45	11.83	12.86	-2.41	12.86
363	5.01	15.09	14.67	12.76	2.33	12.76
364	10.05	16.33	14.49	12.67	3.66	12.67
365	7.69	14.61	14.68	12.58	2.03	12.58

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B. Day by Day DATA for Davos – (QAIST)

Day	H_{45} [MJ/m²]	Ta_d [°C]	Ta_n [°C]	T_{main} [°C]	Ta_d-T_{main} [°C]	T_{cold} [°C]
1	2.55	-1.25	-4.03	4.83	-6.08	4.83
2	18.61	-6.10	-4.98	4.82	-10.92	4.82
3	16.45	1.13	-1.04	4.81	-3.69	4.81
4	7.87	2.75	-0.70	4.80	-2.05	4.80
5	5.77	0.68	-0.13	4.79	-4.11	4.79
6	2.36	-1.21	-8.07	4.78	-5.99	4.78
7	15.50	-16.33	-22.88	4.77	-21.10	4.77
8	6.14	-9.68	-3.70	4.76	-14.44	4.76
9	6.03	-0.15	0.21	4.75	-4.90	4.75
10	4.47	-0.13	-2.44	4.75	-4.88	4.75
11	11.19	-0.37	-4.05	4.74	-5.11	4.74
12	4.80	-2.18	-4.01	4.73	-6.91	4.73
13	18.03	-5.74	-10.01	4.72	-10.46	4.72
14	17.50	-4.93	-5.69	4.72	-9.65	4.72
15	19.03	0.54	-3.91	4.71	-4.17	4.71
16	10.92	-0.72	-5.28	4.70	-5.42	4.70
17	15.16	-2.28	-6.57	4.70	-6.98	4.70
18	18.93	-4.19	-7.66	4.69	-8.88	4.69
19	19.33	-4.63	-7.42	4.68	-9.31	4.68
20	19.76	-4.82	-9.83	4.68	-9.50	4.68
21	20.08	-6.77	-10.22	4.67	-11.44	4.67
22	16.59	-6.31	-10.60	4.67	-10.98	4.67
23	11.58	-7.15	-8.46	4.66	-11.81	4.66
24	8.92	-8.57	-10.07	4.66	-13.23	4.66
25	11.81	-10.35	-17.95	4.65	-15.00	4.65
26	12.01	-7.93	-6.26	4.65	-12.58	4.65
27	5.55	-5.52	-6.38	4.64	-10.16	4.64
28	12.50	-6.23	-9.36	4.64	-10.87	4.64
29	0.78	-7.03	-5.62	4.63	-11.66	4.63
30	8.61	-0.21	-1.84	4.63	-4.84	4.63
31	7.66	-2.87	-9.34	4.63	-7.50	4.63
32	23.53	-7.17	-11.03	4.62	-11.79	4.62
33	23.15	-5.18	-6.97	4.62	-9.80	4.62
34	14.95	-2.71	-4.93	4.62	-7.33	4.62
35	17.79	-1.03	-4.42	4.61	-5.64	4.61
36	22.30	-0.01	-6.36	4.61	-4.62	4.61
37	24.09	-2.29	-2.86	4.61	-6.90	4.61
38	5.74	-0.81	-4.23	4.61	-5.42	4.61
39	13.47	-2.83	-1.83	4.61	-7.44	4.61
40	25.11	1.85	-1.31	4.60	-2.75	4.60
41	4.29	3.49	-2.42	4.60	-1.11	4.60
42	12.73	0.78	-1.66	4.60	-3.82	4.60
43	22.87	3.32	0.19	4.60	-1.28	4.60
44	10.84	-2.50	-5.06	4.60	-7.10	4.60
45	18.39	-0.03	-1.52	4.60	-4.63	4.60
46	4.07	-3.88	-6.31	4.60	-8.48	4.60
47	14.79	-7.07	-10.16	4.60	-11.67	4.60
48	9.60	-9.35	-10.88	4.60	-13.95	4.60
49	16.97	-10.33	-12.98	4.60	-14.93	4.60
50	10.24	-11.74	-16.97	4.60	-16.34	4.60
51	26.10	-6.81	-7.95	4.60	-11.41	4.60

52	18.72	-5.33	-12.98	4.60	-9.93	4.60
53	22.76	-10.78	-9.48	4.61	-15.39	4.61
54	24.05	-7.56	-13.33	4.61	-12.17	4.61
55	28.19	-7.80	-12.51	4.61	-12.41	4.61
56	27.33	-4.10	-7.68	4.61	-8.71	4.61
57	7.73	-1.59	-2.83	4.61	-6.20	4.61
58	6.94	-1.07	-0.15	4.62	-5.69	4.62
59	8.20	0.18	-3.61	4.62	-4.45	4.62
60	14.89	-5.75	-7.83	4.62	-10.37	4.62
61	15.60	-6.80	-11.53	4.63	-11.43	4.63
62	27.66	-7.09	-11.51	4.63	-11.72	4.63
63	28.24	-3.88	-8.18	4.64	-8.52	4.64
64	23.33	-1.94	-7.53	4.64	-6.58	4.64
65	25.06	-0.02	-4.37	4.64	-4.66	4.64
66	12.55	1.71	-3.13	4.65	-2.94	4.65
67	28.48	3.09	-1.78	4.65	-1.56	4.65
68	29.12	4.74	-1.51	4.66	0.08	4.66
69	26.50	4.56	-2.77	4.66	-0.10	4.66
70	27.55	2.97	-1.39	4.67	-1.70	4.67
71	24.41	1.03	-3.19	4.67	-3.64	4.67
72	28.00	3.88	-1.90	4.68	-0.81	4.68
73	20.64	3.82	2.06	4.69	-0.87	4.69
74	18.35	4.15	0.91	4.69	-0.54	4.69
75	15.80	0.34	-1.46	4.70	-4.36	4.70
76	6.70	0.33	-1.18	4.71	-4.38	4.71
77	8.22	1.23	-0.10	4.71	-3.48	4.71
78	11.70	2.05	-0.04	4.72	-2.67	4.72
79	26.32	3.05	-1.43	4.73	-1.68	4.73
80	28.25	6.42	0.63	4.74	1.68	4.74
81	5.73	-0.99	-4.63	4.74	-5.73	4.74
82	20.16	-1.08	-0.58	4.75	-5.83	4.75
83	18.77	5.17	0.71	4.76	0.41	4.76
84	5.99	-3.74	-9.48	4.77	-8.51	4.77
85	9.69	-7.93	-9.99	4.78	-12.71	4.78
86	30.78	-6.17	-5.19	4.78	-10.95	4.78
87	17.13	-2.94	-4.26	4.79	-7.73	4.79
88	16.52	-4.95	-7.59	4.80	-9.75	4.80
89	29.87	-1.36	-3.38	4.81	-6.17	4.81
90	28.49	0.99	-1.51	4.82	-3.83	4.82
91	23.24	7.09	2.11	4.83	2.26	4.83
92	18.15	6.65	2.73	4.84	1.81	4.84
93	28.74	6.93	2.48	4.85	2.08	4.85
94	26.69	9.46	3.69	4.86	4.60	4.86
95	23.47	8.22	4.71	4.87	3.35	4.87
96	13.55	5.69	-1.82	4.88	0.81	4.88
97	29.85	4.22	3.42	4.89	-0.67	4.89
98	8.09	3.96	0.35	4.90	-0.94	4.90
99	8.70	4.03	0.59	4.91	-0.89	4.91
100	12.82	0.95	-1.86	4.92	-3.97	4.92
101	27.77	2.12	-0.49	4.94	-2.82	4.94
102	8.96	-3.33	-6.41	4.95	-8.28	4.95
103	24.99	2.20	-1.71	4.96	-2.76	4.96
104	26.38	-0.68	-2.20	4.97	-5.65	4.97
105	24.31	-0.56	-2.56	4.98	-5.54	4.98
106	13.60	-0.43	-0.88	4.99	-5.42	4.99

107	26.42	1.93	-3.66	5.00	-3.08	5.00
108	29.56	2.39	0.01	5.02	-2.63	5.02
109	29.92	6.49	1.35	5.03	1.46	5.03
110	30.60	9.59	2.28	5.04	4.55	5.04
111	29.62	8.87	3.64	5.05	3.82	5.05
112	14.61	7.26	2.69	5.07	2.19	5.07
113	8.60	5.43	2.83	5.08	0.35	5.08
114	17.42	-1.34	-4.13	5.09	-6.43	5.09
115	31.15	5.43	0.36	5.10	0.33	5.10
116	25.05	3.54	-1.03	5.12	-1.58	5.12
117	26.88	4.21	0.63	5.13	-0.92	5.13
118	18.92	-4.36	-7.30	5.14	-9.50	5.14
119	20.47	-3.88	-3.33	5.16	-9.04	5.16
120	11.13	0.31	0.31	5.17	-4.86	5.17
121	21.02	3.97	1.52	5.18	-1.21	5.18
122	9.73	1.45	-1.80	5.20	-3.75	5.20
123	18.13	-1.51	-3.33	5.21	-6.72	5.21
124	18.43	3.73	0.25	5.22	-1.50	5.22
125	17.91	5.29	0.96	5.24	0.05	5.24
126	27.89	8.62	4.67	5.25	3.37	5.25
127	13.60	7.51	0.53	5.26	2.25	5.26
128	8.25	1.49	0.48	5.28	-3.79	5.28
129	11.64	2.68	1.19	5.29	-2.62	5.29
130	18.75	5.68	2.06	5.30	0.38	5.30
131	27.28	8.70	7.73	5.32	3.38	5.32
132	23.60	10.71	5.46	5.33	5.38	5.33
133	18.54	9.24	6.18	5.34	3.90	5.34
134	28.44	10.47	4.20	5.36	5.11	5.36
13	23.01	9.76	4.45	5.37	4.39	4.72
136	21.43	12.03	5.59	5.39	6.64	5.39
137	28.75	12.92	6.72	5.40	7.52	5.40
138	10.52	10.47	4.33	5.41	5.06	5.41
139	24.77	11.63	7.15	5.43	6.20	5.43
140	13.20	7.48	5.21	5.44	2.04	5.44
141	13.11	7.64	4.69	5.46	2.18	5.46
142	11.44	3.88	2.22	5.47	-1.60	5.47
143	16.87	6.72	1.95	5.48	1.24	5.48
144	27.46	11.69	6.50	5.50	6.19	5.50
145	17.25	13.03	7.21	5.51	7.52	5.51
146	22.48	15.97	9.10	5.52	10.45	5.52
147	18.33	15.33	9.33	5.54	9.79	5.54
148	16.81	10.53	7.98	5.55	4.98	5.55
149	18.19	8.88	6.23	5.56	3.32	5.56
150	21.61	10.83	6.05	5.58	5.25	5.58
151	27.97	13.22	5.48	5.59	7.63	5.59
152	20.53	14.48	7.89	5.60	8.88	5.60
153	15.15	10.98	5.68	5.62	5.36	5.62
154	24.80	14.24	8.09	5.63	8.61	5.63
155	26.35	17.03	9.73	5.64	11.39	5.64
156	23.64	17.84	11.12	5.66	12.18	5.66
157	5.35	9.70	6.78	5.67	4.03	5.67
158	29.75	14.91	8.37	5.68	9.23	5.68
159	29.61	18.84	10.62	5.70	13.14	5.70
160	18.87	14.89	9.13	5.71	9.18	5.71
161	14.84	12.62	5.88	5.72	6.90	5.72

162	26.15	12.15	6.40	5.73	6.42	5.73
163	28.99	13.63	8.28	5.75	7.88	5.75
164	10.92	8.17	5.11	5.76	2.41	5.76
165	3.83	5.09	3.97	5.77	-0.68	5.77
166	9.36	3.39	0.97	5.78	-2.39	5.78
167	10.24	1.33	0.03	5.80	-4.48	5.80
168	20.06	5.54	1.74	5.81	-0.27	5.81
169	14.30	5.76	3.38	5.82	-0.06	5.82
170	20.91	10.12	5.62	5.83	4.29	5.83
171	14.93	10.71	7.90	5.84	4.87	5.84
172	20.83	12.86	7.11	5.85	7.01	5.85
173	23.55	10.43	7.23	5.86	4.57	5.86
174	20.54	13.03	7.58	5.88	7.15	5.88
175	18.04	12.91	7.55	5.89	7.02	5.89
176	18.22	14.85	9.37	5.90	8.95	5.90
177	18.43	14.63	8.97	5.91	8.72	5.91
178	6.59	10.49	7.57	5.92	4.57	5.92
179	7.71	8.38	3.48	5.93	2.45	5.93
180	28.06	10.78	6.02	5.94	4.84	5.94
181	22.14	12.43	5.69	5.95	6.48	5.95
182	25.80	11.98	7.86	5.96	6.02	5.96
183	22.56	17.45	13.49	5.97	11.48	5.97
184	18.89	17.48	12.38	5.98	11.50	5.98
185	18.93	9.47	6.48	5.99	3.48	5.99
186	27.85	14.78	9.58	6.00	8.78	6.00
187	20.84	17.28	10.92	6.01	11.27	6.01
188	20.49	14.64	9.43	6.02	8.62	6.02
189	27.47	17.03	11.50	6.02	11.01	6.02
190	27.82	21.35	12.51	6.03	15.32	6.03
191	23.30	18.19	12.69	6.04	12.15	6.04
192	26.73	18.92	12.38	6.05	12.87	6.05
193	26.64	18.33	12.26	6.06	12.27	6.06
194	23.58	18.38	13.50	6.06	12.32	6.06
195	20.24	18.35	10.68	6.07	12.28	6.07
196	22.76	18.83	11.20	6.08	12.75	6.08
197	24.70	20.18	11.17	6.09	14.09	6.09
198	13.95	13.63	9.61	6.09	7.54	6.09
199	27.51	14.25	9.90	6.10	8.15	6.10
200	20.21	13.66	10.57	6.11	7.55	6.11
201	13.87	15.37	11.47	6.11	9.26	6.11
202	17.15	16.02	10.38	6.12	9.90	6.12
203	19.76	13.35	10.12	6.13	7.22	6.13
204	15.49	12.87	9.00	6.13	6.74	6.13
205	11.06	9.33	7.50	6.14	3.19	6.14
206	7.01	9.33	7.37	6.14	3.19	6.14
207	3.28	8.05	7.15	6.15	1.90	6.15
208	4.80	6.97	4.51	6.15	0.82	6.15
209	5.40	5.61	3.58	6.16	-0.55	6.16
210	25.92	13.65	8.86	6.16	7.49	6.16
211	17.38	17.24	12.50	6.16	11.08	6.16
212	6.77	9.53	7.62	6.17	3.36	6.17
213	15.88	12.63	9.15	6.17	6.46	6.17
214	4.84	9.49	9.90	6.18	3.31	6.18
215	22.69	15.73	12.23	6.18	9.55	6.18
216	19.36	13.01	6.42	6.18	6.83	6.18

217	11.01	4.18	1.49	6.19	-2.02	6.19
218	18.64	6.72	6.51	6.19	0.53	6.19
219	18.55	8.53	4.90	6.19	2.34	6.19
220	25.12	11.81	7.64	6.19	5.62	6.19
221	10.39	11.72	8.12	6.19	5.53	6.19
222	28.68	11.47	7.65	6.20	5.27	6.20
223	28.60	13.69	9.23	6.20	7.49	6.20
224	7.08	12.75	9.50	6.20	6.55	6.20
225	24.10	15.53	11.29	6.20	9.33	6.20
226	19.45	17.72	13.13	6.20	11.52	6.20
227	6.99	15.36	9.06	6.20	9.16	6.20
228	22.69	15.91	11.61	6.20	9.71	6.20
229	27.87	20.53	15.89	6.20	14.33	6.20
230	6.90	13.28	11.65	6.20	7.08	6.20
231	15.92	15.64	10.73	6.20	9.44	6.20
232	29.36	17.38	11.76	6.20	11.18	6.20
233	29.31	18.87	12.12	6.20	12.67	6.20
234	29.19	19.58	13.58	6.20	13.38	6.20
235	10.96	16.04	10.08	6.19	9.85	6.19
236	7.71	13.03	9.92	6.19	6.84	6.19
237	8.43	6.55	5.40	6.19	0.36	6.19
238	24.62	12.10	8.60	6.19	5.91	6.19
239	3.91	9.52	7.03	6.19	3.33	6.19
240	10.02	9.04	4.33	6.18	2.86	6.18
241	26.88	13.53	8.26	6.18	7.35	6.18
242	29.29	16.05	9.63	6.18	9.87	6.18
243	29.02	17.54	10.40	6.17	11.37	6.17
244	10.13	15.43	11.71	6.17	9.26	6.17
245	4.41	3.37	2.08	6.17	-2.80	6.17
246	14.45	9.42	8.51	6.16	3.26	6.16
247	19.83	14.37	9.13	6.16	8.21	6.16
248	22.77	15.98	11.78	6.15	9.83	6.15
249	14.66	14.87	10.86	6.15	8.72	6.15
250	27.26	13.03	6.24	6.14	6.89	6.14
251	26.68	12.32	6.75	6.14	6.18	6.14
252	26.45	14.56	10.28	6.13	8.43	6.13
253	21.69	14.79	9.46	6.13	8.66	6.13
254	20.43	14.32	10.75	6.12	8.20	6.12
255	9.52	12.18	9.20	6.12	6.06	6.12
256	4.93	6.59	2.03	6.11	0.48	6.11
257	7.08	3.16	1.56	6.10	-2.94	6.10
258	9.88	3.12	1.28	6.10	-2.98	6.10
259	12.98	3.88	2.63	6.09	-2.21	6.09
260	18.83	5.46	4.00	6.08	-0.62	6.08
261	20.94	7.21	5.83	6.08	1.13	6.08
262	24.28	9.98	6.80	6.07	3.91	6.07
263	24.86	10.39	6.85	6.06	4.33	6.06
264	22.27	9.88	7.93	6.05	3.83	6.05
265	24.44	11.83	6.87	6.05	5.78	6.05
266	12.14	8.53	6.75	6.04	2.49	6.04
267	24.89	11.38	6.12	6.03	5.35	6.03
268	6.96	9.62	6.73	6.02	3.60	6.02
269	23.95	14.33	7.59	6.01	8.32	6.01
270	23.09	13.57	7.71	6.00	7.57	6.00
271	20.76	16.72	10.38	5.99	10.73	5.99

272	11.78	11.58	7.88	5.98	5.60	5.98
273	6.97	6.15	7.33	5.97	0.18	5.97
274	15.26	12.33	8.26	5.96	6.37	5.96
275	23.32	10.98	5.86	5.95	5.03	5.95
276	21.77	11.87	7.53	5.94	5.93	5.94
277	1.87	6.73	2.36	5.93	0.80	5.93
278	11.32	3.97	-0.18	5.92	-1.95	5.92
279	24.30	9.68	4.57	5.91	3.77	5.91
280	11.78	7.51	5.33	5.90	1.61	5.90
281	7.99	1.50	-2.23	5.89	-4.39	5.89
282	26.28	6.08	2.38	5.88	0.20	5.88
283	26.25	9.91	3.63	5.87	4.04	5.87
284	26.02	12.01	6.41	5.86	6.15	5.86
285	10.90	12.09	8.79	5.85	6.24	5.85
286	11.97	10.53	5.18	5.84	4.69	5.84
287	23.79	12.29	5.73	5.82	6.47	5.82
288	13.54	13.17	8.07	5.81	7.36	5.81
289	5.62	11.32	7.32	5.80	5.52	5.80
290	9.08	10.23	5.98	5.79	4.44	5.79
291	7.54	7.06	4.29	5.78	1.28	5.78
292	13.44	7.79	2.88	5.76	2.03	5.76
293	6.18	4.98	4.12	5.75	-0.77	5.75
294	18.05	7.67	2.85	5.74	1.93	5.74
295	23.78	7.38	0.48	5.73	1.65	5.73
296	18.51	6.06	0.75	5.71	0.35	5.71
297	22.96	5.25	-0.33	5.70	-0.45	5.70
298	14.31	5.15	2.65	5.69	-0.54	5.69
299	19.67	5.46	1.48	5.68	-0.22	5.68
300	4.60	-0.48	-4.42	5.66	-6.14	5.66
301	21.38	1.78	3.54	5.65	-3.88	5.65
302	4.22	1.85	1.98	5.64	-3.79	5.64
303	20.47	1.78	-1.59	5.62	-3.85	5.62
304	3.56	3.62	-0.38	5.61	-1.99	5.61
305	4.47	4.95	0.94	5.60	-0.65	5.60
306	3.10	0.22	-4.06	5.58	-5.36	5.58
307	18.18	-3.46	-9.05	5.57	-9.03	5.57
308	19.30	-3.18	-8.60	5.56	-8.74	5.56
309	19.90	-1.38	-0.08	5.54	-6.92	5.54
310	3.41	2.23	-1.12	5.53	-3.31	5.53
311	19.12	2.08	0.08	5.52	-3.44	5.52
312	19.86	6.26	-1.12	5.50	0.76	5.50
313	19.30	2.47	-0.95	5.49	-3.02	5.49
314	19.23	3.13	-1.18	5.48	-2.36	5.48
315	18.70	5.91	-2.14	5.46	0.45	5.46
316	17.19	1.82	-2.11	5.45	-3.63	5.45
317	13.93	4.09	2.47	5.43	-1.34	5.43
318	4.54	6.07	4.89	5.42	0.65	5.42
319	10.75	7.82	2.67	5.41	2.41	5.41
320	11.70	5.63	1.47	5.39	0.24	5.39
321	11.66	5.37	2.44	5.38	-0.01	5.38
322	5.46	1.41	-4.07	5.37	-3.96	5.37
323	12.68	1.49	1.02	5.35	-3.86	5.35
324	7.75	3.59	-0.15	5.34	-1.75	5.34
325	2.74	-1.18	-4.80	5.32	-6.50	5.32
326	6.40	-0.73	-2.18	5.31	-6.04	5.31

327	2.03	-2.59	-6.67	5.30	-7.89	5.30
328	9.84	-6.10	-8.63	5.28	-11.38	5.28
329	15.57	-0.98	-2.60	5.27	-6.25	5.27
330	16.94	-0.18	-2.80	5.26	-5.44	5.26
331	5.10	-3.55	-11.17	5.24	-8.79	5.24
332	17.06	-5.75	-8.81	5.23	-10.98	5.23
333	16.56	-4.58	-6.97	5.22	-9.80	5.22
334	16.68	-2.52	-4.05	5.20	-7.72	5.20
335	13.54	1.33	-1.28	5.19	-3.87	5.19
336	10.15	3.95	-0.10	5.18	-1.23	5.18
337	11.97	1.67	-1.58	5.16	-3.49	5.16
338	15.17	0.53	-2.19	5.15	-4.62	5.15
339	16.08	-0.18	-2.15	5.14	-5.32	5.14
340	4.16	1.93	0.38	5.12	-3.20	5.12
341	5.15	1.76	0.83	5.11	-3.35	5.11
342	7.86	4.82	2.50	5.10	-0.28	5.10
343	6.53	0.83	-1.25	5.09	-4.27	5.09
344	10.29	2.49	-2.75	5.07	-2.58	5.07
345	8.76	-4.80	-6.90	5.06	-9.86	5.06
346	5.03	-4.59	-5.69	5.05	-9.64	5.05
347	15.56	-3.88	-5.18	5.04	-8.92	5.04
348	5.93	-3.69	-8.44	5.02	-8.71	5.02
349	4.96	-3.27	-0.28	5.01	-8.28	5.01
350	1.11	1.73	1.02	5.00	-3.28	5.00
351	6.70	2.99	0.15	4.99	-2.00	4.99
352	2.07	-5.75	-7.88	4.98	-10.73	4.98
353	12.38	-8.57	-8.47	4.96	-13.53	4.96
354	4.40	0.13	-0.30	4.95	-4.83	4.95
355	8.31	-3.63	-10.40	4.94	-8.57	4.94
356	15.65	-9.63	-10.43	4.93	-14.56	4.93
357	13.19	-8.78	-9.05	4.92	-13.70	4.92
358	12.21	-10.08	-12.74	4.91	-14.99	4.91
359	2.38	-4.18	-5.39	4.90	-9.08	4.90
360	16.03	-5.16	-6.81	4.89	-10.05	4.89
361	13.20	-1.59	-3.83	4.88	-6.47	4.88
362	4.39	-1.38	-4.39	4.87	-6.25	4.87
363	15.54	-6.64	-15.43	4.86	-11.50	4.86
364	16.65	-10.22	-8.48	4.85	-15.07	4.85
365	15.16	-2.83	-3.52	4.84	-7.67	4.84

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C. Day by Day DATA for Stockholm – (QAIST)

Day	H_{45} {MJ/m²}	Ta_d {°C}	Ta_n {°C}	T_{main} {°C}	Ta_d-T_{main} {°C}	T_{cold} [°C]
1	0.55	3.83	2.10	3.91	-0.08	3.91
2	0.39	1.46	0.20	3.83	-2.37	3.83
3	0.37	0.64	-0.49	3.76	-3.12	3.76
4	0.83	0.20	-1.53	3.68	-3.48	3.68
5	4.35	-0.10	-1.76	3.61	-3.71	3.61
6	0.98	-2.81	-2.81	3.54	-6.35	3.54
7	1.07	-0.93	-1.89	3.47	-4.40	3.47
8	0.95	-3.64	-5.58	3.40	-7.04	3.40
9	1.23	-5.17	-5.04	3.34	-8.51	3.34
10	1.88	-4.15	-3.86	3.27	-7.42	3.27
11	2.68	-1.57	-5.72	3.21	-4.78	3.21
12	1.27	-15.48	-17.45	3.15	-18.63	3.15
13	2.38	-12.59	-9.30	3.09	-15.68	3.09
14	0.59	-7.15	-8.51	3.03	-10.18	3.03
15	0.42	-9.71	-8.74	2.98	-12.69	2.98
16	1.25	-5.52	-3.61	2.92	-8.44	2.92
17	2.20	-1.58	-0.72	2.87	-4.45	2.87
18	1.56	2.09	2.03	2.82	-0.73	2.82
19	1.17	4.25	1.35	2.77	1.48	2.77
20	4.10	1.25	-0.40	2.72	-1.47	2.72
21	4.04	2.95	2.91	2.67	0.28	2.67
22	0.83	3.23	1.93	2.63	0.60	2.63
23	0.20	1.62	-0.59	2.58	-0.96	2.58
24	0.57	-4.94	-7.08	2.54	-7.48	2.54
25	4.96	-0.62	0.95	2.50	-3.12	2.50
26	4.56	4.87	3.69	2.47	2.40	2.47
27	9.31	4.16	2.63	2.43	1.73	2.43
28	2.76	1.36	-0.89	2.40	-1.04	2.40
29	6.02	3.16	3.19	2.36	0.80	2.36
30	3.51	3.79	2.01	2.33	1.46	2.33
31	6.96	4.50	4.80	2.31	2.19	2.31
32	10.59	4.81	2.62	2.28	2.53	2.28
33	1.44	3.01	0.94	2.25	0.76	2.25
34	1.63	0.20	-3.70	2.23	-2.03	2.23
35	7.57	-8.28	-7.20	2.21	-10.49	2.21
36	3.82	-0.30	-1.28	2.19	-2.49	2.19
37	3.82	-3.68	-4.80	2.17	-5.85	2.17
38	3.61	-2.24	-4.63	2.16	-4.40	2.16
39	3.78	-6.23	-9.30	2.14	-8.37	2.14
40	4.07	-8.72	-8.43	2.13	-10.85	2.13
41	7.73	-4.58	-6.11	2.12	-6.70	2.12
42	11.38	-3.51	-5.63	2.11	-5.62	2.11
43	3.95	-4.55	-5.13	2.11	-6.66	2.11
44	14.98	1.71	-5.23	2.10	-0.39	2.10
45	14.22	-12.35	-16.36	2.10	-14.45	2.10
46	15.92	-9.88	-6.39	2.10	-11.98	2.10
47	4.12	-1.15	-0.43	2.10	-3.25	2.10
48	0.88	0.48	-1.54	2.10	-1.62	2.10
49	0.45	-4.39	-5.20	2.11	-6.50	2.11
50	1.64	-2.02	-1.48	2.12	-4.14	2.12
51	2.62	1.88	1.11	2.13	-0.26	2.13

52	9.57	5.69	5.45	2.14	3.55	2.14
53	10.98	6.29	3.35	2.15	4.14	2.15
54	5.88	2.19	-0.48	2.16	0.03	2.16
55	2.67	3.08	-0.38	2.18	0.90	2.18
56	10.31	2.44	-1.98	2.20	0.24	2.20
57	6.05	0.01	-1.90	2.22	-2.21	2.22
58	15.63	3.89	2.65	2.24	1.65	2.24
59	5.45	3.82	2.07	2.27	1.55	2.27
60	4.42	-0.02	-1.17	2.29	-2.32	2.29
61	2.37	0.22	-2.63	2.32	-2.10	2.32
62	19.74	-1.63	-5.03	2.35	-3.98	2.35
63	14.23	-2.26	-3.39	2.38	-4.64	2.38
64	4.13	-1.90	-2.53	2.41	-4.31	2.41
65	5.16	-0.45	-2.54	2.45	-2.90	2.45
66	8.13	-0.18	-5.59	2.48	-2.66	2.49
67	19.79	-5.13	-8.48	2.52	-7.65	2.52
68	19.53	-3.48	-5.31	2.56	-6.04	2.56
69	6.60	-3.11	-3.29	2.61	-5.72	2.61
70	4.28	-0.53	-2.23	2.65	-3.18	2.65
71	14.25	-0.72	-3.36	2.70	-3.42	2.70
72	13.38	0.91	-1.96	2.74	-1.83	2.74
73	16.08	2.13	-1.46	2.79	-0.66	2.79
74	15.55	2.79	0.23	2.84	-0.05	2.84
75	4.69	2.23	3.58	2.89	-0.67	2.89
76	5.85	8.21	5.44	2.95	5.26	2.95
77	11.29	4.80	2.24	3.00	1.80	3.00
78	5.30	3.71	1.14	3.06	0.65	3.06
79	6.01	1.19	-1.18	3.12	-1.93	3.12
80	13.92	3.15	0.46	3.18	-0.03	3.18
81	17.11	6.79	2.04	3.24	3.55	3.24
82	12.46	3.59	2.17	3.31	0.28	3.31
83	3.56	4.51	1.97	3.37	1.14	3.37
84	11.14	5.03	0.25	3.44	1.59	3.44
85	15.19	4.38	0.52	3.51	0.87	3.51
86	17.10	8.48	3.65	3.58	4.90	3.58
87	20.15	8.17	2.02	3.65	4.52	3.65
88	21.36	7.61	1.73	3.72	3.89	3.72
89	23.66	7.98	3.93	3.79	4.19	3.79
90	10.23	9.27	1.98	3.87	5.40	3.87
91	24.98	4.27	1.22	3.95	0.32	3.95
92	4.59	3.76	-0.02	4.02	-0.26	4.02
93	23.62	1.61	-1.43	4.10	-2.49	4.10
94	25.77	7.86	5.23	4.18	3.68	4.18
95	26.90	12.82	7.51	4.27	8.55	4.27
96	18.28	11.20	6.69	4.35	6.85	4.35
97	24.99	13.78	9.28	4.43	9.35	4.43
98	10.78	12.06	8.59	4.52	7.54	4.52
99	6.85	10.56	7.57	4.61	5.95	4.61
100	23.79	14.46	9.87	4.69	9.77	4.69
101	22.55	15.52	8.75	4.78	10.74	4.78
102	14.06	10.22	5.89	4.87	5.35	4.87
103	14.26	9.73	5.23	4.96	4.77	4.96
104	19.72	10.66	4.34	5.06	5.60	5.06
105	22.56	8.27	3.78	5.15	3.12	5.15
106	9.45	6.83	5.03	5.24	1.59	5.24

107	6.70	8.19	3.53	5.34	2.85	5.34
108	12.01	5.57	0.94	5.44	0.13	5.44
109	9.04	3.32	-0.28	5.53	-2.21	5.53
110	20.72	6.10	1.65	5.63	0.47	5.63
111	13.26	5.30	0.48	5.73	-0.43	5.73
112	18.92	5.98	5.73	5.83	0.15	5.83
113	2.93	6.55	4.88	5.93	0.62	5.93
114	1.53	4.26	3.18	6.03	-1.77	6.03
115	8.68	8.23	3.26	6.13	2.10	6.13
116	20.75	8.63	4.69	6.24	2.39	6.24
117	8.63	9.09	3.14	6.34	2.75	6.34
118	25.75	8.11	-0.30	6.44	1.67	6.44
119	26.35	4.59	-2.36	6.55	-1.96	6.55
120	16.64	3.03	2.02	6.65	-3.62	6.65
121	21.80	11.08	7.17	6.76	4.32	6.76
122	24.90	13.20	8.27	6.87	6.33	6.87
123	25.61	13.94	9.00	6.97	6.97	6.97
124	16.18	10.87	9.63	7.08	3.79	7.08
125	24.21	14.26	9.81	7.19	7.07	7.19
126	18.86	14.31	9.23	7.30	7.01	7.30
127	11.15	10.25	6.77	7.40	2.85	7.40
128	16.84	9.44	4.39	7.51	1.93	7.51
129	24.20	9.30	4.05	7.62	1.68	7.62
130	16.87	6.74	6.08	7.73	-0.99	7.73
131	13.67	10.56	3.69	7.84	2.72	7.84
132	24.26	6.71	2.76	7.95	-1.24	7.95
133	27.60	11.09	4.42	8.06	3.03	8.06
134	28.34	9.93	5.97	8.17	1.76	8.17
13	28.40	14.07	8.39	8.28	5.79	3.09
136	18.99	12.71	6.52	8.39	4.32	8.39
137	21.87	11.93	8.71	8.50	3.43	8.50
138	4.55	9.53	7.33	8.61	0.92	8.61
139	23.17	14.03	11.46	8.72	5.31	8.72
140	22.05	19.22	13.55	8.83	10.39	8.83
141	21.20	18.31	13.10	8.94	9.37	8.94
142	16.94	15.13	12.88	9.05	6.08	9.05
143	12.00	15.38	11.50	9.16	6.22	9.16
144	24.60	15.35	9.83	9.27	6.08	9.27
145	25.78	16.01	11.88	9.38	6.63	9.38
146	12.43	15.73	12.83	9.49	6.24	9.49
147	11.60	16.27	14.41	9.60	6.67	9.60
148	18.55	19.30	12.88	9.70	9.60	9.70
149	19.67	15.53	11.89	9.81	5.72	9.81
150	8.50	13.55	9.16	9.92	3.63	9.92
151	30.25	16.11	10.43	10.03	6.08	10.03
152	29.28	16.03	11.06	10.13	5.90	10.13
153	28.73	16.51	11.72	10.24	6.27	10.24
154	23.03	15.73	10.50	10.35	5.38	10.35
155	22.74	12.91	9.82	10.45	2.46	10.45
156	28.08	15.73	10.34	10.56	5.17	10.56
157	26.37	15.08	9.62	10.66	4.42	10.66
158	29.55	15.01	9.22	10.76	4.25	10.76
159	26.44	12.73	8.54	10.87	1.86	10.87
160	26.61	14.57	10.13	10.97	3.60	10.97
161	23.68	14.93	11.94	11.07	3.86	11.07

162	18.29	16.50	11.98	11.17	5.33	11.17
163	19.17	16.27	14.58	11.27	5.00	11.27
164	16.19	18.42	15.47	11.37	7.05	11.37
165	5.60	15.52	12.50	11.47	4.05	11.47
166	24.76	17.43	12.43	11.56	5.87	11.56
167	24.52	17.66	12.43	11.66	6.00	11.66
168	24.67	16.71	13.34	11.76	4.95	11.76
169	27.88	19.99	17.73	11.85	8.14	11.85
170	16.28	22.78	19.03	11.94	10.84	11.94
171	15.74	21.89	18.86	12.04	9.85	12.04
172	16.72	22.08	17.18	12.13	9.95	12.13
173	19.38	21.43	16.12	12.22	9.21	12.22
174	21.14	20.50	17.06	12.31	8.19	12.31
175	13.79	19.33	17.55	12.39	6.94	12.39
176	12.45	21.32	15.12	12.48	8.84	12.48
177	25.24	18.53	15.46	12.57	5.96	12.57
178	6.77	16.20	13.65	12.65	3.55	12.65
179	14.31	16.46	13.99	12.73	3.73	12.73
180	15.40	15.64	14.41	12.82	2.82	12.82
181	9.18	17.03	14.36	12.90	4.13	12.90
182	19.54	19.48	16.13	12.98	6.50	12.98
183	11.97	19.96	19.14	13.05	6.91	13.05
184	8.98	20.99	16.44	13.13	7.86	13.13
185	13.05	16.80	14.14	13.21	3.59	13.21
186	16.08	17.64	13.86	13.28	4.36	13.28
187	14.23	16.68	12.94	13.35	3.33	13.35
188	23.07	18.43	17.20	13.42	5.01	13.42
189	11.06	20.53	19.36	13.49	7.04	13.49
190	18.27	25.38	20.23	13.56	11.82	13.56
191	12.96	22.48	18.25	13.63	8.85	13.63
192	10.12	19.80	15.51	13.69	6.11	13.69
193	28.62	20.85	15.94	13.76	7.09	13.76
194	23.09	20.79	15.05	13.82	6.97	13.82
195	11.15	14.92	13.05	13.88	1.04	13.88
196	16.61	15.46	12.18	13.94	1.52	13.94
197	25.24	17.89	13.76	14.00	3.89	14.00
198	23.71	18.82	17.29	14.05	4.77	14.05
199	17.05	22.39	20.03	14.11	8.28	14.11
200	20.02	23.52	16.56	14.16	9.36	14.16
201	23.60	17.91	17.91	14.21	3.70	14.21
202	29.08	27.54	23.93	14.26	13.28	14.26
203	11.13	25.44	20.16	14.30	11.14	14.30
204	28.25	24.92	18.65	14.35	10.57	14.35
205	27.09	23.01	17.17	14.39	8.62	14.39
206	18.36	19.50	14.44	14.44	5.06	14.44
207	17.47	16.73	14.48	14.48	2.25	14.48
208	22.29	20.06	16.24	14.52	5.54	14.51
209	26.99	22.18	18.94	14.55	7.63	14.55
210	24.48	25.28	17.50	14.59	10.69	14.59
211	26.39	19.27	18.48	14.62	4.65	14.62
212	10.31	23.17	17.20	14.65	8.52	14.65
213	24.44	22.09	15.12	14.68	7.41	14.68
214	17.46	19.32	11.64	14.71	4.61	14.71
215	24.70	17.42	11.08	14.73	2.69	14.73
216	20.60	15.18	13.16	14.76	0.42	14.76

217	8.66	17.48	12.47	14.78	2.70	14.78
218	20.34	17.48	11.79	14.80	2.68	14.80
219	20.84	15.63	12.72	14.82	0.81	14.82
220	19.56	18.91	13.03	14.84	4.07	14.84
221	14.50	16.48	13.83	14.85	1.63	14.85
222	14.13	18.49	15.98	14.86	3.63	14.86
223	14.61	21.70	17.82	14.87	6.83	14.87
224	21.50	22.92	17.99	14.88	8.04	14.88
225	6.29	18.26	15.98	14.89	3.37	14.89
226	19.29	22.61	17.07	14.90	7.71	14.90
227	20.18	20.87	17.63	14.90	5.97	14.90
228	4.93	18.97	18.35	14.90	4.07	14.90
229	9.13	23.26	20.31	14.90	8.36	14.90
230	17.03	24.77	20.43	14.90	9.87	14.90
231	22.94	25.31	21.33	14.89	10.42	14.89
232	14.36	24.03	19.02	14.89	9.14	14.89
233	7.17	18.73	15.81	14.88	3.85	14.88
234	7.51	16.55	13.14	14.87	1.68	14.87
235	21.10	18.43	15.03	14.86	3.57	14.86
236	10.84	18.44	16.80	14.84	3.60	14.84
237	18.08	23.60	16.83	14.83	8.77	14.83
238	25.52	19.43	15.73	14.81	4.62	14.81
239	26.41	23.41	18.93	14.79	8.62	14.79
240	11.95	20.99	16.41	14.77	6.22	14.77
241	10.95	18.13	15.58	14.75	3.38	14.75
242	10.81	18.66	17.47	14.72	3.94	14.72
243	26.23	24.49	15.55	14.69	9.80	14.69
244	26.58	19.02	15.72	14.67	4.35	14.67
245	5.67	18.02	15.48	14.64	3.38	14.64
246	7.62	18.93	15.88	14.60	4.33	14.60
247	15.41	21.39	18.98	14.57	6.82	14.57
248	8.48	20.23	14.91	14.53	5.70	14.53
249	9.27	18.04	12.34	14.50	3.54	14.50
250	10.01	14.20	11.10	14.46	-0.26	14.46
251	6.89	16.33	10.43	14.42	1.91	14.42
252	16.32	12.68	6.43	14.37	-1.70	14.37
253	20.15	12.99	6.21	14.33	-1.34	14.33
254	22.59	10.20	4.74	14.28	-4.08	14.28
255	19.88	12.23	6.84	14.23	-2.01	14.23
256	20.18	11.97	9.16	14.18	-2.21	14.18
257	20.46	18.38	12.29	14.13	4.25	14.13
258	21.82	16.33	11.80	14.08	2.25	14.08
259	6.88	15.04	9.98	14.02	1.02	14.02
260	8.68	8.18	9.04	13.97	-5.80	13.97
261	7.23	15.38	10.68	13.91	1.47	13.91
262	17.63	13.61	10.06	13.85	-0.24	13.85
263	4.59	12.09	11.58	13.79	-1.70	13.79
264	1.75	13.47	10.62	13.73	-0.26	13.73
265	18.18	12.27	9.23	13.66	-1.39	13.66
266	8.38	14.39	13.64	13.60	0.79	13.60
267	8.00	16.01	15.20	13.53	2.48	13.53
268	7.86	15.28	12.90	13.46	1.82	13.46
269	6.87	12.81	10.23	13.39	-0.58	13.39
270	10.52	12.65	8.07	13.32	-0.67	13.32
271	11.64	9.76	9.30	13.24	-3.48	13.24

272	9.06	14.28	11.25	13.17	1.11	13.17
273	11.20	13.71	8.64	13.09	0.62	13.09
274	1.25	6.01	3.81	13.02	-7.01	13.02
275	1.91	5.42	4.01	12.94	-7.52	12.94
276	2.89	6.82	3.09	12.86	-6.04	12.86
277	19.14	10.28	6.31	12.78	-2.50	12.78
278	7.06	9.92	7.75	12.69	-2.77	12.69
279	6.52	10.16	7.80	12.61	-2.45	12.61
280	13.53	11.55	8.27	12.52	-0.97	12.52
281	4.10	9.10	7.22	12.44	-3.34	12.44
282	4.65	11.28	10.63	12.35	-1.08	12.35
283	3.77	13.31	13.17	12.26	1.05	12.26
284	1.64	13.88	10.99	12.17	1.71	12.17
285	13.81	13.58	10.13	12.08	1.50	12.08
286	14.45	13.11	9.75	11.99	1.12	11.99
287	15.98	12.72	9.26	11.90	0.82	11.90
288	14.55	12.47	7.50	11.80	0.67	11.80
289	14.72	9.26	7.26	11.71	-2.45	11.71
290	5.47	9.35	9.06	11.61	-2.26	11.61
291	2.32	9.34	6.40	11.52	-2.18	11.52
292	3.92	7.28	7.45	11.42	-4.15	11.42
293	2.39	11.45	8.82	11.32	0.13	11.32
294	13.05	11.06	7.16	11.22	-0.16	11.22
295	4.76	7.93	5.38	11.12	-3.20	11.12
296	3.77	5.78	4.70	11.02	-5.25	11.02
297	4.85	7.06	5.01	10.92	-3.86	10.92
298	4.47	3.78	0.68	10.81	-7.03	10.82
299	16.37	2.28	1.03	10.71	-8.44	10.71
300	3.55	3.07	1.26	10.61	-7.54	10.61
301	1.98	-0.37	1.08	10.50	-10.87	10.50
302	1.30	5.10	4.30	10.40	-5.30	10.40
303	2.78	4.69	2.25	10.29	-5.60	10.29
304	5.87	4.14	-0.90	10.19	-6.05	10.19
305	4.43	-2.43	-5.30	10.08	-12.51	10.08
306	3.66	0.38	-0.11	9.97	-9.60	9.97
307	0.79	-0.33	-1.11	9.87	-10.20	9.87
308	0.46	0.17	-0.96	9.76	-9.59	9.76
309	3.06	0.41	0.46	9.65	-9.24	9.65
310	0.58	0.85	-1.53	9.54	-8.69	9.54
311	11.74	2.02	2.33	9.43	-7.41	9.43
312	0.83	5.28	5.05	9.32	-4.05	9.32
313	2.44	8.27	6.57	9.21	-0.94	9.22
314	5.40	8.78	8.72	9.11	-0.33	9.11
315	2.33	10.02	7.69	9.00	1.02	9.00
316	2.09	6.37	2.99	8.89	-2.52	8.89
317	2.82	4.43	2.33	8.78	-4.35	8.78
318	9.92	5.54	3.14	8.67	-3.13	8.67
319	0.74	2.18	0.51	8.56	-6.38	8.56
320	4.71	3.73	3.89	8.44	-4.72	8.45
321	0.94	5.88	3.16	8.33	-2.45	8.34
322	8.16	2.93	3.67	8.22	-5.30	8.23
323	6.25	9.46	9.97	8.11	1.35	8.12
324	1.88	8.33	4.94	8.00	0.32	8.01
325	7.52	7.20	5.48	7.89	-0.69	7.90
326	6.53	7.48	6.86	7.79	-0.32	7.79

327	1.87	7.98	5.83	7.68	0.30	7.68
328	0.31	1.07	0.15	7.57	-6.50	7.57
329	0.36	3.65	3.67	7.46	-3.81	7.46
330	0.28	2.19	0.85	7.35	-5.16	7.35
331	0.47	1.46	0.13	7.24	-5.78	7.24
332	0.29	-1.48	-3.20	7.13	-8.61	7.13
333	0.28	-5.18	-4.02	7.03	-12.21	7.03
334	0.17	-1.93	-1.05	6.92	-8.85	6.92
335	0.45	0.99	-1.52	6.81	-5.82	6.81
336	0.99	-3.76	-2.10	6.71	-10.47	6.71
337	1.00	3.07	2.51	6.60	-3.53	6.60
338	3.40	2.47	-0.59	6.50	-4.03	6.50
339	0.58	-0.59	-2.50	6.39	-6.98	6.39
340	0.72	-1.84	-2.65	6.29	-8.13	6.29
341	0.58	-0.96	-1.76	6.19	-7.15	6.19
342	1.85	0.83	-1.03	6.08	-5.26	6.08
343	0.36	-2.98	-4.05	5.98	-8.96	5.98
344	2.68	0.96	-1.61	5.88	-4.92	5.88
345	0.46	-5.33	-3.70	5.78	-11.11	5.78
346	0.73	1.70	0.75	5.68	-3.98	5.68
347	4.38	-1.73	-2.51	5.58	-7.31	5.58
348	3.91	4.33	4.15	5.48	-1.16	5.49
349	3.08	4.37	3.51	5.39	-1.02	5.39
350	3.14	6.93	5.70	5.29	1.64	5.29
351	3.11	3.52	2.81	5.20	-1.68	5.20
352	0.40	6.43	5.83	5.10	1.33	5.10
353	0.46	5.29	2.98	5.01	0.28	5.01
354	3.07	5.55	1.13	4.92	0.63	4.92
355	1.88	-4.13	-4.14	4.83	-8.96	4.83
356	3.18	4.14	3.64	4.74	-0.60	4.74
357	0.22	-0.92	-4.98	4.65	-5.57	4.65
358	0.08	-9.23	-11.95	4.56	-13.79	4.56
359	0.76	-11.06	-9.07	4.48	-15.54	4.48
360	0.45	-6.11	-7.12	4.39	-10.50	4.39
361	4.30	-5.26	-4.48	4.31	-9.57	4.31
362	0.29	-2.79	-0.33	4.22	-7.01	4.22
363	0.22	1.58	1.19	4.14	-2.57	4.14
364	0.55	2.55	0.97	4.06	-1.51	4.06
365	0.55	0.85	1.70	3.98	-3.13	3.98

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D. Day by Day DATA for Wurzburg – (QAIST)

Day	H_{45} {MJ/m²}	Ta_d {ºC}	Ta_n {ºC}	T_{main} {ºC}	Ta_d-T_{main} {ºC}	T_{cold} [ºC]
1	1.25	0.51	0.90	5.40	-4.89	7.85
2	1.08	-0.16	-1.73	5.33	-5.48	7.81
3	15.18	-1.93	-2.67	5.25	-7.18	7.78
4	15.02	-3.21	-5.08	5.18	-8.39	7.74
5	6.22	-5.53	-6.14	5.11	-10.64	7.71
6	1.11	-2.48	-0.15	5.04	-7.52	7.68
7	1.62	0.43	1.73	4.97	-4.53	7.64
8	1.75	2.81	3.43	4.90	-2.09	7.61
9	1.22	3.37	3.58	4.83	-1.47	7.58
10	1.15	4.70	2.98	4.77	-0.07	7.55
11	1.25	2.46	-0.84	4.71	-2.25	7.52
12	9.06	-2.18	-6.38	4.65	-6.83	7.49
13	1.71	-5.22	-3.93	4.59	-9.80	7.46
14	1.21	-0.86	4.72	4.53	-5.39	7.44
15	1.77	3.88	6.88	4.47	-0.59	7.41
16	1.35	3.88	1.15	4.42	-0.53	7.38
17	1.66	0.20	1.88	4.37	-4.17	7.36
18	1.29	1.78	2.23	4.31	-2.53	7.34
19	1.32	2.58	1.03	4.26	-1.68	7.31
20	1.32	1.14	-2.94	4.22	-3.07	7.29
21	15.96	-3.27	-5.00	4.17	-7.44	7.27
22	4.72	-3.80	-3.02	4.13	-7.93	7.25
23	1.38	-2.39	0.65	4.08	-6.47	7.23
24	1.81	0.45	-1.68	4.04	-3.59	7.21
25	17.93	-0.63	-3.94	4.00	-4.63	7.19
26	17.56	-5.01	-6.53	3.96	-8.97	7.17
27	17.55	-6.24	-9.05	3.93	-10.17	7.15
28	18.38	-7.79	-9.83	3.90	-11.69	7.14
29	1.66	-9.07	-5.71	3.86	-12.93	7.12
30	1.54	-3.04	-1.75	3.83	-6.87	7.11
31	1.85	-0.50	-1.98	3.80	-4.30	7.10
32	13.99	-2.90	-2.76	3.78	-6.68	7.08
33	1.62	-2.20	-2.48	3.75	-5.95	7.07
34	2.33	-4.70	-11.01	3.73	-8.43	7.06
35	17.88	-12.98	-14.58	3.71	-16.69	7.05
36	1.70	-8.73	2.26	3.69	-12.41	7.04
37	12.99	4.45	3.39	3.67	0.78	7.03
38	1.76	1.98	2.58	3.66	-1.68	7.03
39	6.03	3.70	4.28	3.64	0.06	7.02
40	2.87	5.16	3.39	3.63	1.53	7.01
41	2.21	4.88	3.66	3.62	1.25	7.01
42	1.88	5.51	5.74	3.61	1.90	7.01
43	3.00	4.51	3.32	3.61	0.90	7.00
44	1.95	4.01	2.11	3.60	0.41	7.00
45	7.95	2.75	1.08	3.60	-0.85	7.00
46	4.03	2.77	0.46	3.60	-0.83	7.00
47	2.59	2.23	1.70	3.60	-1.38	7.00
48	4.48	2.28	1.66	3.61	-1.32	7.00
49	2.11	3.53	2.78	3.61	-0.08	7.00
50	4.95	2.43	-1.12	3.62	-1.18	7.01
51	3.81	1.12	-1.85	3.63	-2.51	7.01

52	10.73	0.26	1.68	3.64	-3.38	7.02
53	2.26	1.38	-0.83	3.65	-2.28	7.02
54	22.83	0.09	-3.16	3.67	-3.57	7.03
55	17.85	-0.38	0.69	3.68	-4.07	7.04
56	2.96	4.69	3.12	3.70	0.99	7.05
57	2.39	1.63	0.47	3.72	-2.10	7.06
58	3.18	1.11	-0.99	3.74	-2.63	7.07
59	22.33	2.05	-1.19	3.77	-1.72	7.08
60	20.78	2.98	0.65	3.79	-0.81	7.09
61	20.61	2.33	-0.35	3.82	-1.50	7.10
62	5.30	1.47	3.09	3.85	-2.38	7.12
63	12.72	3.51	1.27	3.88	-0.37	7.13
64	23.50	4.36	-0.93	3.91	0.44	7.15
65	24.51	3.23	-0.65	3.95	-0.72	7.16
66	24.82	4.62	0.15	3.99	0.63	7.18
67	20.44	4.79	2.85	4.03	0.77	7.20
68	9.68	5.96	5.57	4.07	1.89	7.22
69	3.19	8.43	6.83	4.11	4.33	7.24
70	3.27	8.65	6.95	4.15	4.50	7.26
71	5.40	8.35	4.90	4.20	4.15	7.28
72	10.12	8.72	7.13	4.24	4.47	7.30
73	3.67	6.45	3.26	4.29	2.16	7.32
74	6.33	6.42	5.84	4.34	2.07	7.35
75	3.11	8.07	4.96	4.40	3.67	7.37
76	3.35	3.27	3.16	4.45	-1.18	7.40
77	3.25	5.06	7.51	4.51	0.55	7.42
78	6.04	9.82	6.29	4.56	5.25	7.45
79	3.51	4.58	3.47	4.62	-0.04	7.48
80	13.50	6.61	3.96	4.68	1.93	7.51
81	3.36	1.08	0.54	4.74	-3.66	7.54
82	3.39	0.81	-0.03	4.81	-4.00	7.57
83	3.72	1.76	1.18	4.87	-3.11	7.60
84	4.67	2.94	1.43	4.94	-2.00	7.63
85	4.63	4.10	3.53	5.01	-0.91	7.66
86	13.18	6.93	5.03	5.08	1.85	7.69
87	6.81	5.66	4.13	5.15	0.51	7.73
88	3.64	2.67	2.26	5.22	-2.55	7.76
89	10.72	3.36	1.35	5.30	-1.94	7.79
90	3.72	5.53	8.19	5.37	0.15	7.83
91	5.41	10.79	10.12	5.45	5.34	7.87
92	25.08	18.52	12.57	5.53	12.99	7.90
93	9.75	12.59	5.38	5.61	6.99	7.94
94	10.29	10.73	11.47	5.69	5.05	7.98
95	4.91	10.60	8.64	5.77	4.83	8.02
96	24.62	12.96	8.14	5.85	7.11	8.05
97	13.55	6.76	3.45	5.94	0.82	8.09
98	16.62	2.72	0.90	6.02	-3.30	8.13
99	14.12	4.86	0.55	6.11	-1.25	8.17
100	26.08	6.33	4.27	6.20	0.13	8.22
101	25.60	9.60	6.46	6.29	3.32	8.26
102	23.17	10.49	6.20	6.38	4.12	8.30
103	24.63	11.70	7.56	6.47	5.23	8.34
104	10.94	11.73	6.69	6.56	5.18	8.39
105	22.47	14.23	9.89	6.65	7.57	8.43
106	20.90	12.98	7.83	6.75	6.24	8.47

107	18.31	12.53	9.36	6.84	5.69	8.52
108	25.23	15.73	12.54	6.94	8.80	8.56
109	24.80	17.97	12.43	7.04	10.93	8.61
110	25.33	16.68	9.83	7.13	9.54	8.66
111	27.27	14.63	5.05	7.23	7.39	8.70
112	26.23	7.24	5.71	7.33	-0.09	8.75
113	22.33	10.40	5.85	7.43	2.97	8.80
114	5.71	8.85	8.87	7.53	1.32	8.84
115	12.30	11.38	7.18	7.64	3.75	8.89
116	19.95	10.24	7.30	7.74	2.50	8.94
117	22.51	11.66	8.49	7.84	3.82	8.99
118	25.43	14.29	10.74	7.95	6.35	9.04
119	13.57	13.60	8.85	8.05	5.55	9.09
120	4.84	9.11	7.89	8.16	0.95	9.13
121	8.70	8.08	5.08	8.26	-0.18	9.18
122	9.43	6.36	6.08	8.37	-2.01	9.23
123	4.93	6.92	5.78	8.47	-1.56	9.28
124	14.56	10.43	7.55	8.58	1.85	9.33
125	25.56	13.33	10.53	8.69	4.65	9.38
126	24.45	16.02	11.73	8.80	7.22	9.44
127	27.97	17.75	14.07	8.90	8.85	9.49
128	19.95	19.87	14.44	9.01	10.85	9.54
129	26.83	20.47	16.09	9.12	11.34	9.59
130	27.01	20.42	16.24	9.23	11.19	9.64
131	24.75	22.08	16.07	9.34	12.74	9.69
132	24.13	19.07	11.28	9.45	9.62	9.74
133	25.38	16.73	10.89	9.56	7.17	9.79
134	5.43	11.18	8.13	9.67	1.51	9.85
13	13.48	11.10	8.28	9.78	1.32	7.46
136	22.18	15.73	13.40	9.89	5.84	9.95
137	21.27	19.07	13.02	10.00	9.07	10.00
138	22.75	18.70	13.34	10.11	8.59	10.05
139	13.08	17.22	11.67	10.22	7.00	10.10
140	22.56	18.13	14.75	10.33	7.80	10.15
141	27.36	19.37	13.82	10.44	8.93	10.21
142	13.40	18.70	13.42	10.55	8.15	10.26
143	26.30	17.70	11.36	10.66	7.04	10.31
144	27.11	17.38	12.15	10.77	6.61	10.36
145	6.99	15.27	10.88	10.88	4.39	10.41
146	5.51	6.08	3.62	10.99	-4.92	10.46
147	9.35	8.67	6.99	11.10	-2.43	10.51
148	6.11	5.79	6.36	11.20	-5.41	10.56
149	5.61	9.22	6.28	11.31	-2.09	10.62
150	22.08	14.34	13.19	11.42	2.92	10.67
151	10.88	19.26	11.87	11.53	7.73	10.72
152	5.62	11.23	10.30	11.63	-0.41	10.77
153	5.63	11.20	12.97	11.74	-0.54	10.82
154	9.16	18.08	12.87	11.85	6.23	10.87
155	28.19	19.49	17.98	11.95	7.54	10.91
156	23.31	20.49	14.78	12.06	8.43	10.96
157	19.88	16.86	11.40	12.16	4.70	11.01
158	15.15	15.05	14.13	12.26	2.79	11.06
159	14.95	17.59	17.29	12.37	5.22	11.11
160	20.77	20.68	13.87	12.47	8.21	11.16
161	15.68	14.73	11.67	12.57	2.16	11.20

162	24.95	16.53	11.68	12.67	3.86	11.25
163	21.75	17.82	13.78	12.77	5.05	11.30
164	24.29	19.78	16.70	12.87	6.91	11.34
165	24.53	23.09	19.43	12.97	10.12	11.39
166	19.73	22.09	13.58	13.06	9.03	11.44
167	19.12	18.26	14.11	13.16	5.10	11.48
168	24.25	17.94	13.27	13.25	4.69	11.53
169	26.62	20.02	15.67	13.35	6.67	11.57
170	27.37	21.66	17.01	13.44	8.22	11.61
171	9.26	14.70	10.93	13.53	1.17	11.66
172	17.20	16.18	13.10	13.63	2.55	11.70
173	25.19	17.48	15.83	13.72	3.76	11.74
174	17.49	17.59	12.99	13.80	3.79	11.78
175	24.20	14.56	11.93	13.89	0.67	11.83
176	23.39	18.66	14.13	13.98	4.68	11.87
177	24.72	19.73	15.32	14.07	5.66	11.91
178	23.21	14.08	12.53	14.15	-0.07	11.95
179	14.11	13.94	10.51	14.23	-0.29	11.98
180	26.56	16.65	12.96	14.31	2.34	12.02
181	26.94	19.82	16.03	14.40	5.42	12.06
182	23.97	22.40	17.09	14.47	7.93	12.10
183	10.66	13.60	13.87	14.55	-0.95	12.13
184	25.49	14.22	10.79	14.63	-0.41	12.17
185	17.52	12.86	10.60	14.70	-1.84	12.21
186	25.21	13.85	12.68	14.78	-0.93	12.24
187	11.17	15.03	14.34	14.85	0.18	12.27
188	15.74	20.06	16.34	14.92	5.14	12.31
189	26.12	21.47	18.55	14.99	6.48	12.34
190	24.28	24.38	18.28	15.06	9.32	12.37
191	24.26	22.03	16.41	15.13	6.90	12.40
192	23.63	19.36	15.63	15.19	4.17	12.43
193	25.84	19.93	16.53	15.26	4.67	12.46
194	22.68	23.05	18.73	15.32	7.73	12.49
195	26.31	26.28	23.56	15.38	10.90	12.52
196	16.99	24.06	18.22	15.44	8.62	12.55
197	22.73	22.13	17.63	15.49	6.64	12.58
198	21.47	22.03	18.93	15.55	6.48	12.60
199	19.19	21.93	15.23	15.60	6.33	12.63
200	16.37	17.25	15.30	15.66	1.59	12.65
201	10.02	16.98	15.35	15.71	1.27	12.68
202	12.66	19.24	16.78	15.76	3.48	12.70
203	18.44	19.58	16.28	15.80	3.78	12.72
204	26.43	22.84	19.51	15.85	6.99	12.74
205	12.92	19.47	13.86	15.89	3.58	12.76
206	16.61	13.83	11.95	15.93	-2.10	12.78
207	16.60	16.33	12.63	15.98	0.35	12.80
208	15.24	17.88	14.68	16.01	1.87	12.82
209	26.13	19.90	15.73	16.05	3.85	12.84
210	27.27	21.31	17.75	16.09	5.22	12.85
211	25.82	23.70	20.04	16.12	7.58	12.87
212	25.73	26.05	20.62	16.15	9.90	12.88
213	17.29	24.88	17.56	16.18	8.70	12.90
214	26.16	23.23	18.21	16.21	7.02	12.91
215	16.35	19.18	18.04	16.23	2.95	12.92
216	17.16	20.31	16.93	16.26	4.05	12.93

217	12.05	18.88	16.82	16.28	2.60	12.94
218	20.32	19.95	16.68	16.30	3.65	12.95
219	26.84	26.49	23.90	16.32	10.17	12.96
220	6.99	17.47	13.89	16.33	1.14	12.97
221	26.40	17.37	11.91	16.35	1.02	12.98
222	26.58	18.58	14.91	16.36	2.22	12.98
223	26.34	23.24	18.55	16.37	6.87	12.99
224	24.84	24.57	20.03	16.38	8.19	12.99
225	19.05	23.03	18.63	16.39	6.64	13.00
226	13.35	22.50	19.88	16.40	6.10	13.00
227	5.36	19.87	17.30	16.40	3.47	13.00
228	12.30	18.20	14.52	16.40	1.80	13.00
229	16.17	19.92	18.50	16.40	3.52	13.00
230	4.72	18.87	17.48	16.40	2.47	13.00
231	20.16	23.45	19.93	16.39	7.06	13.00
232	4.65	17.66	14.40	16.39	1.27	12.99
233	4.52	14.07	12.64	16.38	-2.31	12.99
234	4.49	14.18	11.98	16.37	-2.19	12.99
235	7.42	14.40	13.81	16.36	-1.96	12.98
236	11.22	17.63	15.18	16.34	1.29	12.97
237	24.26	22.65	16.81	16.33	6.32	12.97
238	26.03	21.50	19.22	16.31	5.19	12.96
239	4.30	18.25	13.79	16.29	1.96	12.95
240	4.61	13.98	13.58	16.27	-2.29	12.94
241	18.71	18.96	15.75	16.25	2.71	12.93
242	14.56	20.51	17.94	16.22	4.29	12.92
243	24.43	24.53	19.28	16.20	8.33	12.90
244	25.45	25.84	18.89	16.17	9.67	12.89
245	25.94	26.28	20.16	16.14	10.14	12.88
246	21.79	24.32	19.34	16.11	8.21	12.86
247	25.08	25.11	20.76	16.07	9.04	12.85
248	25.36	24.48	20.11	16.04	8.44	12.83
249	11.73	21.15	15.66	16.00	5.15	12.81
250	11.02	17.92	13.81	15.96	1.96	12.79
251	3.85	16.58	16.62	15.92	0.65	12.77
252	11.85	16.96	12.51	15.88	1.08	12.75
253	8.32	14.37	9.06	15.83	-1.46	12.73
254	21.85	14.53	10.04	15.78	-1.25	12.71
255	22.94	18.57	19.18	15.74	2.83	12.69
256	5.02	20.55	17.72	15.69	4.86	12.66
257	23.24	23.92	18.59	15.64	8.28	12.64
258	5.21	18.26	11.25	15.58	2.68	12.62
259	3.55	11.48	9.83	15.53	-4.06	12.59
260	17.30	13.33	9.08	15.47	-2.15	12.56
261	23.53	14.44	11.40	15.41	-0.97	12.54
262	17.56	14.49	11.19	15.35	-0.86	12.51
263	15.93	15.38	12.99	15.29	0.09	12.48
264	7.78	15.24	10.56	15.23	0.01	12.45
265	5.94	10.00	9.17	15.17	-5.17	12.42
266	3.23	9.60	8.63	15.10	-5.50	12.39
267	6.59	10.27	7.03	15.03	-4.76	12.36
268	15.50	9.72	5.71	14.96	-5.24	12.32
269	8.69	8.59	6.53	14.89	-6.30	12.29
270	16.76	10.21	7.23	14.82	-4.61	12.26
271	3.04	9.41	9.16	14.75	-5.34	12.22

272	14.58	11.27	8.12	14.67	-3.40	12.19
273	19.83	10.58	8.98	14.60	-4.02	12.15
274	9.96	10.91	11.95	14.52	-3.61	12.12
275	8.38	12.12	11.05	14.44	-2.32	12.08
276	10.93	12.52	8.98	14.36	-1.84	12.04
277	5.68	8.77	9.26	14.28	-5.51	12.00
278	21.05	12.63	7.03	14.20	-1.58	11.97
279	12.15	10.36	9.44	14.12	-3.76	11.93
280	21.56	14.58	11.81	14.03	0.55	11.89
281	8.71	13.68	10.63	13.94	-0.27	11.85
282	6.29	12.27	12.43	13.86	-1.59	11.81
283	6.67	14.87	10.73	13.77	1.10	11.76
284	7.15	10.53	10.48	13.68	-3.16	11.72
285	22.28	15.15	13.04	13.59	1.56	11.68
286	4.92	17.94	15.93	13.50	4.44	11.64
287	4.25	10.86	8.34	13.40	-2.54	11.59
288	6.13	9.91	7.67	13.31	-3.40	11.55
289	4.12	10.65	8.22	13.22	-2.57	11.50
290	6.80	10.98	9.74	13.12	-2.15	11.46
291	2.94	9.50	5.66	13.02	-3.52	11.41
292	2.70	6.67	5.49	12.93	-6.26	11.37
293	9.86	8.17	4.73	12.83	-4.66	11.32
294	4.00	8.30	7.58	12.73	-4.43	11.28
295	3.03	8.28	8.01	12.63	-4.36	11.23
296	2.71	7.51	7.28	12.53	-5.02	11.18
297	3.25	8.09	4.81	12.43	-4.34	11.13
298	3.46	6.79	5.14	12.32	-5.53	11.09
299	4.69	6.18	5.98	12.22	-6.05	11.04
300	2.41	5.88	3.18	12.12	-6.25	10.99
301	21.41	7.27	5.43	12.01	-4.74	10.94
302	22.07	7.46	2.45	11.91	-4.45	10.89
303	13.24	4.58	2.40	11.80	-7.22	10.84
304	12.99	6.69	9.86	11.70	-5.01	10.79
305	7.73	13.14	12.40	11.59	1.55	10.74
306	5.57	11.89	6.34	11.48	0.41	10.69
307	9.65	9.69	8.67	11.38	-1.69	10.64
308	2.34	10.32	7.23	11.27	-0.95	10.59
309	18.62	10.22	6.57	11.16	-0.94	10.54
310	3.42	10.93	7.88	11.05	-0.12	10.49
311	17.95	7.78	3.87	10.94	-3.17	10.44
312	2.48	7.07	6.00	10.83	-3.76	10.39
313	2.33	6.43	4.93	10.72	-4.30	10.34
314	2.08	4.43	3.44	10.61	-6.19	10.28
315	2.01	1.98	1.94	10.51	-8.53	10.23
316	4.79	4.27	1.69	10.40	-6.13	10.18
317	2.57	2.98	3.66	10.29	-7.31	10.13
318	2.33	4.83	5.86	10.18	-5.35	10.08
319	2.44	5.88	7.19	10.07	-4.20	10.03
320	2.00	6.56	5.33	9.96	-3.40	9.97
321	2.24	4.64	2.51	9.85	-5.20	9.92
322	1.38	3.97	3.43	9.74	-5.77	9.87
323	1.53	4.57	0.69	9.63	-5.06	9.82
324	16.76	2.72	-0.87	9.52	-6.80	9.77
325	16.53	0.63	-1.83	9.41	-8.78	9.72
326	17.28	-0.06	-3.34	9.30	-9.35	9.67

327	9.23	-1.02	-0.10	9.19	-10.20	9.61
328	1.27	1.39	2.33	9.08	-7.69	9.56
329	1.25	2.58	2.02	8.97	-6.39	9.51
330	1.66	4.51	4.84	8.86	-4.35	9.46
331	1.96	5.61	3.38	8.75	-3.14	9.41
332	1.66	2.52	4.87	8.64	-6.13	9.36
333	1.78	4.57	1.68	8.54	-3.97	9.31
334	1.44	5.45	6.78	8.43	-2.98	9.26
335	1.16	9.32	10.45	8.32	0.99	9.21
336	1.28	8.79	1.86	8.22	0.57	9.16
337	11.37	2.03	5.38	8.11	-6.08	9.11
338	1.15	3.38	4.78	8.01	-4.62	9.06
339	1.25	4.48	1.54	7.90	-3.43	9.01
340	1.10	2.18	0.65	7.80	-5.62	8.96
341	1.73	0.55	0.78	7.70	-7.15	8.92
342	1.08	2.27	5.42	7.59	-5.33	8.87
343	1.17	4.92	2.46	7.49	-2.58	8.82
344	1.39	2.07	0.99	7.39	-5.32	8.77
345	1.06	0.88	1.00	7.29	-6.42	8.73
346	1.52	1.66	-0.12	7.19	-5.53	8.68
347	1.05	-3.32	-1.14	7.09	-10.41	8.63
348	7.92	-0.50	-3.12	7.00	-7.50	8.59
349	13.18	-3.48	-2.78	6.90	-10.38	8.54
350	1.04	-2.66	-3.68	6.80	-9.46	8.50
351	1.11	-1.99	-0.84	6.71	-8.70	8.45
352	14.89	-2.40	-7.79	6.61	-9.01	8.41
353	14.07	-7.27	-4.65	6.52	-13.79	8.36
354	1.03	-2.17	-0.96	6.43	-8.60	8.32
355	1.03	0.38	1.06	6.34	-5.95	8.28
356	1.03	2.75	2.02	6.25	-3.50	8.24
357	1.03	2.48	1.83	6.16	-3.68	8.20
358	1.10	2.29	2.53	6.07	-3.78	8.15
359	3.27	2.93	0.02	5.99	-3.05	8.11
360	1.37	0.50	0.95	5.90	-5.40	8.07
361	5.80	0.43	2.63	5.82	-5.39	8.03
362	1.04	3.88	2.31	5.73	-1.86	8.00
363	1.38	4.95	1.48	5.65	-0.70	7.96
364	1.06	3.22	6.03	5.57	-2.36	7.92
365	1.39	3.27	1.38	5.49	-2.23	7.88